PB-229 776

MULTIPURPOSE MODIFICATION OF PLAYA SINKS

Lubbock City-County Health Unit
Lubbock, Texas

31 December 1964

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THIRD ANNUAL PROGRESS REPORT

Lubbock, Texas
December 31, 1964

Multipurpose Modification
OF
PLAYA SINKS

PROJECT NUMBER 29 DIVISION OF WATER SUPPLY AND POLLUTION CONTROL

UNITED STATES PUBLIC HEALTH SERVICE

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in cooperation with

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TEXAS WATER COMMISSION

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ABSTRACT

More than 90% of the surface runoff on the High Plains of Texas is collected in thousands of natural depressions or playa lakes. These occur at the rate of about one per square mile, and each is the terminal drainage basin for a watershed that ranges in size from a few to several thousand acres. The playa lakes vary in size and depth, from a few feet to a mile in diameter, and from a few inches to several feet deep. Although waterholding characteristics vary with soil type, most of the playas contain thick layers of clay and colloidal material which, when wet, swells and becomes relatively impermeable and impedes natural recharge into the underlying aquifer.

In this semi-arid area, the annual loss of water by evaporation exceeds the amount of water accumulated in the playa lakes; thus causing these lakes to be of an intermittent nature and prohibiting their use for sport fishing, recreation, and sustained waterfowl use. The rapid evapo-transpiration of water from these depressions also seriously limits the amount of water that can be reclaimed for agricultural or domestic purposes. Rainfall and consequently runoff and inundation of the playa depression coincide with the peak seasons for breeding of Culex tarsalis, the mosquito vector of arboencephalitis.

Effective utilization of these water resources is the basic goal of this project, Multipurpose Modification of Playa Sinks, which is supported as Project WP-29 of the Division of Water Supply and Pollution Control, United States Public Health Service. Active participants on this project include personnel of the Lubbock City-County Health Unit, High Plains Underground Water Conservation District, and Texas Technological College. The unique multi-disciplinary approach to this water resource utilization problem is enhanced by the technical advice of personnel assigned by the United States Public Health Service, Texas Water Commission, Soil Conservation Service, United States Fish and Wildlife Service, and other interested agencies.

The basic aims of this project are to design, construct and evaluate a series of modifications of these playa lakes. The inter-disciplinary team approach is being used to obtain one or more methods of handling surface water that will serve several purposes rather than one single purpose. The ideal modification would prevent mosquito breeding; maintain water for fish production, recreational use and migrating waterfowl; provide water for irrigation and domestic use; and reclaim valuable land for agricultural production.

Materials and Methods

Ten representative playa lakes were chosen for study during the initial year, 1961-62. These lakes were surveyed and elevation-volume and elevation-area curves constructed. All lakes were equipped with staff and rain gauges. Readings from these were used to maintain continuing area, volume and depth curves. Soil profiles of the lake bed were studied to determine the range of soil types occurring in the area. As time and funds became available, all lakes were equipped with automatic water level recorders for more accurate hydrological records.

Local land owners were interviewed to obtain approximate data on the maximum, the minimum and the range of water impoundment in these playas from one rainfall period to another. Additional information was secured on use of land areas immediately surrounding the playa lakes.

In preliminary studies, the infiltration rates at different contour levels above the lake bottom were correlated with the percent clay and mean particle sizes of soils at these levels.

A study of the ecology of the natural playa depression was begun in the first year to provide a basis for comparison with subsequent ecological changes in the playa lake environment. Primary emphasis was given to a continuous study of mosquito population dynamics, especially of *Culex tarsalis*, and factors causing these population changes. The sampling scheme used to index mosquito numbers consisted of establishing ten equiangular spokes from the center of the lake to the shoreline. Systematic samples were taken every ten paces along a spoke with the initial sampling being randomized at the water edge by the change in water level between sampling dates. Population trends of other invertebrates, wildlife, and water fowl were also followed. Water chemistry factors known to affect aquatic organisms were also evaluated.

These investigations were continued after lake modification to measure ecological and water chemistry changes associated with the modifications.

Specifications for the initial lake modifications were based on data collected during the first year and from criteria developed to yield the maximum possible benefits to each of the following: water conservation; soil conservation; mosquito control; wildlife; fish and waterfowl use; and costs. A synthesis of these factors produced a basic design consisting of a deep, rectangular pit created by both cutting and filling portions of the original lake bed.

Discussion and Results

Simple correlation analysis between rainfall and volume of water caught in playa lakes showed a non-significant value indicating that the amount of water impounded is not necessarily associated with concurrent rainfall. Since the modification design does not affect the runoff characteristics of the watershed, the amount of water delivered to a playa, either modified or unmodified, should be equal. The annual volume caught in all lakes in this study ranged from none to 222.6 acre feet with an overall mean of 59.3 acre feet.

Very poor correlation was found between the rate of evaporation, as determined by the Young Screen Pan, and rate of water loss from playa lakes. Factors contributing to this lack of correlation included: variable rates of percolation at different water levels and heads; local climatic differences; and time series changes in infiltration rate. Infiltration rate, as determined by a double ring infiltrometer varied from 0.00075 feet per hour at the bottom of the lake bed to as high as 0.455 feet per hour on a contour located four feet above the lake bed.

Modified playa sinks have retained enough water to maintain the aquatic environment on an annual basis or to have contributed significant amounts of water for irrigation use. Modification has effectively reclaimed an average of over ten acres of land per lake modified. Comparable land is sold at approximately $500.00 per acre. Therefore, it appears that land development is a significant source of benefits from playa sink modification.

Mosquito production in unmodified basins has been characterized by great variability from year to year and lake to lake. The most striking finding of the entire study has been the complete absence of mosquito production in all modified playa sinks while almost every unmodified lake studied has produced mosquitoes. Since more than 70 percent of the encephalitis vectors are produced in playa sinks, modifications of this type should offer significant reductions in the number of cases of encephalitis in both man and animals.

Studies of other invertebrates indicate a reduction in productivity in the modified lakes as compared with the natural state. Water chemistry evaluations indicate no limiting factors for fish production. Initial stockings of fish appear to be doing quite well. Populations of the mosquito minnow, _Gambusia affinnis affinnis_, have reproduced rapidly from initial stockings each year in unmodified lakes, but have died out each year due to crowding and the intermittent nature of the impoundment.

Summary

A total of five playa sinks have been modified. When adequate provisions for water entry were made, these modifications were highly durable. Water loss through percolation appears to be much higher than expected from reports from other studies.

The modification design has been completely successful in eliminating mosquito breeding. No mosquitoes, either _Culex tarsalis_ or other species, have been found in any of the five modified playas.

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ACKNOWLEDGEMENTS

Project WP-29 has such wide significance to the public health, agriculture, and wildlife of the locality that it draws the interest, support, and cooperation of many agencies and individuals.

Mr. Walter Breedlove, Chief Public Health Engineer of the Lubbock City-County Health Unit, has for years fostered and sponsored the development of this project. His efforts in promoting and organizing the project, his keen interest, valuable advice, and continuing support of this study are appreciated.

Dr. A.D. Hess, and colleagues, Dr. Dick Hayes, and Mr. Bruce Francy, of the United States Public Health Service, Greely, Colorado, have been very helpful in planning the program, resolving technical problems, and securing equipment.

Dr. J.V. Irons, Director of the Laboratories, and Dr. John S. Wiseman, in charge of the Entomology Section, Texas State Health Department, have given their advice and support to the project.

Mr. M.G. Sheldon, U.S. Fish and Wildlife Service, Denver, Colorado, has aided in planning the wildlife phases of the project. Mr. Phillip Summers, also of the U.S. Fish and Wildlife Service, has helped in securing fish for modified lakes.

Mr. John Hobbs, Public Information Office, Texas Technological College, has been very helpful with photography and publicity for the project.

The Texas Water Commission has supplied automatic water level recorders for hydrological studies.

Mr. Vic Hauser, Agricultural Research Service, United States Department of Agriculture, and Mr. Frank Rayner, Texas Water Commission, have been very helpful in advisory capacity in hydrological problems of the project.

The following have also helped as advisors and consultants:

Dr. Thadis W. Box, Department of Agronomy and Range Management, Texas Technological College

Mr. Al Couch, City of Lubbock, Director of Finance

Dr. J.R. Johnston, SWCRD - ARS - USDA, Amarillo, Texas

Mr. Don Krieble, U.S. Fish and Wildlife Service, Lubbock, Texas

Dr. Robert A. Littleford, Chief, Research Grants Section, Division of Water Supply and Pollution Control, Bethesda, Md.

Mr. Elo J. Urbanovsky, Head, Department of Park Administration, Horticulture and Entomology, Texas Technological College

Mr. Cecil S. Williams, Director of Wildlife Research, Denver, Colorado

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Mr. Elwin Smith and Mr. Bill Cornelius, Lubbock City-County Health Unit, Lubbock
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Dr. Willie L. Ulich and Mr. Marvin Dvoracek, Department of Agricultural Engineering,
Texas Technological College

INTRODUCTION

This report presents results of investigations conducted during the third year of the project "Multipurpose Modification of Playa Sinks." This project was initiated in September of 1961 as a multi-disciplinary study conducted by the Lubbock City-County Health Unit, High Plains Underground Water Conservation District, Texas Technological College, and various state and federal agencies. Support for this project has been furnished by Research Grant WP-29 from the Division of Water Supply and Pollution Control, United States Public Health Service.

The objectives of this project are to design, construct and evaluate a series of physical modifications of playa sinks for the mutual benefits of soil and water conservation, mosquito control, and fish and wildlife use. In the first year of the project, a series of ten representative playa sinks were chosen for study. These lakes were surveyed on one-half and one foot contour lines and data from these surveys were used to construct scale maps, elevation-area, and elevation-volume curves for each lake. Each lake was equipped with staff gauges, and selected lakes were equipped with water level recorders. All lakes were regularly sampled for mosquito production, populations of other selected invertebrates, wildlife and waterfowl usage, and water quality. Additional studies were conducted on an economic evaluation of playa lakes and present use of agricultural land in and around the lakes.

In the second year of the project, three of the ten original study lakes were physically modified. These modifications were of the same basic design which required evacuation of a large pit in the bottom of the sink and filling of a portion of the lake bed with the spoil from the pit. Among the variables evaluated were slope of the pit walls, orientation of the pit, and pit dimensions. In addition, based on experiences gained in the first two modifications, water entrance and hence erosion was controlled in the third modification by a berm surrounding the pit. Only one entrance to the pit was provided. The evaluation of the biological and water quality factors were continued for both modified and unmodified lakes.

Studies in the period covered in the third year consist of new modifications on two additional lakes, additional work to control water erosion on two of the previously modified lakes, basic data collection studies of infiltration rates and evaluation of techniques for analysis of the data obtained in this study. Continuing studies were conducted on the ecology of modified and unmodified playas. Methods of statistical analysis have been chosen or are under evaluation for all phases of the study.

A BRIEF SYNOPSIS OF THE CURRENT SEASON

The year was, generally speaking, a very dry year and altogether different from the preceding ones. Late spring rainfall was well below normal and highly variable in distribution over the study area. During late May and early June, variable and generally small amounts of water were impounded in eight of the ten study lakes. All unmodified lakes were dry from August 5 to September 13, when most again impounded small amounts of water.

Very little rain and no runoff occurred at Lake No. I, (Huckabee) during the fall and winter of 1963-64. A water level recorder was installed at this lake on March 5, 1964. The lake received its first water in May and had small amounts of water in it from the middle of May through the first week in July. The lake was then dry until the 13th of September when a small amount of runoff was impounded.

Lake No. II (Knowles) had a carryover of 11.4 acre-feet of water into this study year (September 1, 1963). This lake contained water from September through November and was then dry until March. Irrigation runoff or "tailwater" collected in the lake during March. The first rainfall runoff did not occur until the middle of May. A lake pump was installed at the lake in June and water was pumped to irrigate the farmer's crop. The lake was pumped dry by the middle of July, and remained dry throughout the rest of the year.

Lake No. III (Hufstedler) was modified during the study year 1962-63. The lake had received water in the spring of 1963 before a recorder tower was installed. Therefore, all readings at Lake No. III (Hufstedler) were taken from a staff gauge. During April of 1964 the lake pit was pumped dry to permit additional modification work. At this time a recorder tower and automatic water level recorder were installed. This lake had a carryover of 13.2 acre-feet of water on September 1, 1963, and retained water from September of 1963 through March of 1964. Two and a half acre-feet of the 13.2 acre-feet carry-over remained at the time the lake was pumped dry in April. Had this lake not been modified, it undoubtedly would have been dry long before this. Following the adjustments mentioned above, a small amount of water collected during May, and additional water was added in June. The lake had water in it throughout the rest of the year.

Lake No. IV (Lubbock Christian College) was originally modified during the study year 1962-63. A total volume of 22.3 acre-feet of water was carried over from September 1, 1963 into this study year. Water was in the lake from September of 1963 through January of 1964. At this time L.C.C. personnel began a program of pumping water into the lake and then out of the lake. Such erratic water level fluctuations occurred that it was nearly impossible to analyze the water level chart. Also, for some unexplained reason, considerable vandalism occurred to the recording device. In addition, the L.C.C. personnel removed dirt from the lake bed on two different occasions during the spring and summer of 1964. Because of all these circumstances, a valid analysis of runoff information at Lake No. IV after January of 1964 was impossible and the information gathered was so erratic that it was meaningless.

Lake No. V (Kitten) received a very small amount of water on September 1, 1963. The lake was dry by the middle of September, however, and remained dry until May of 1964. A very small amount of water was caught during May but the lake was soon dry. Additional rainwater was added in June of 1964 and remained through most of July. In comparison with the two previous years, Lake No. V had a very small amount of water during 1963-64. The lake had been modified during the spring of 1963 and this was the main reason that any water was retained.

Lake No. VI (Holland) was dry from September of 1963 through April of 1964. The lake was modified during the spring of 1964 and a rain in May put some water into the modification. This lake retained water throughout the rest of the year. The A-35 recorder and recording rain gage were installed at this lake during June. A continuous water level record is available from June through August.

Lake No. VII (Cooper) was dropped from the lake program during the year 1962-63. Therefore, no water level information was available for this lake.

Lake No. VIII (Burgett) had a small amount of water in it on September 1, 1963. However, the landowner pumped it dry during the first few days of the month and the lake remained dry until June of 1964. This lake was modified during the spring of 1964 and during June a small amount of water collected in the modification. The lake held water throughout the remainder of the year. A water level recorder was installed in this lake during June and provided daily readings throughout the remainder of the year.

Lake No. IX (Cox) and Lake No. X (Dupree) did not receive enough water to record during the study year. Automatic recorders have been installed at these lakes and are available to record future runoff and retention data.

Lake No. XI (Krueger) had a carryover of 27.2 acre-feet of water on September 1, 1963, but was dry by the middle of October and remained dry until May of 1964. The lake was equipped with a water level recorder during March of 1964. A rain on May 16, 1964 put some water into the lake and it contained water until the middle of August but was dry throughout the rest of the study year.

The cumulative vulume of water caught by each lake, the cumulative rainfall at each lake, the daily volume of water in each lake, the daily surface area of each lake and a histogram of the daily rainfall at each lake are shown in Figures II-1 through II-6 of Appendix II. Because the data were so erratic, no curves were drawn for Lake No. IV (L. C. C.) from February through August. No curves were drawn for Lake No. IX (Cox) and Lake No. X (Reese) because they were dry throughout the year and no curve was drawn for Lake No. VII (Cooper) because it has been omitted from the study. Table 1 shows the total amount of water caught by each lake during the 1961-62 study year, 1962-63 study year and the 1963-64 study year. Table 2 is a monthly balance sheet for 1961 to 1964.

Table 1. Total Amount of Water Caught by Each Lake During the study years 1961-62, 1962-63 and 1962-64.

Lake	Volume caught in acre-feet of water (1961-62)	Volume caught in acre-feet of water (1962-63)	Volume caught in acre-feet of water (1963-64)	Volume caught in acre-feet of water (3-year average)
Lake No. I (Huckabee)	None	55.8	27.3	27.7
Lake No. II (Knowles)	14.7	114.3	77.9	69.0
Lake No. III (Hufstedler)	5.8	102.4	11.2	39.8
Lake No. IV (L.C.C.)	34.4	142.1	#	88.3*
Lake No. V (Kitten)	148.3	152.7	3.7	101.6
Lake No. VI (Holland)	7.5	140.6	23.5	57.2
Lake No. VII (Cooper)	66.2	No Record	No Record	---
Lake No. VIII (Burgett)	No Record	149.7	3.7	76.7*
Lake No. IX (Cox)	None	34.9	None	11.6
Lake No. X (Dupree)	17.2	51.1	None	22.8
Lake No. XI (Krueger)	No Record	222.6	53.2	137.9*

*Note: This is a two year average.
#Note: Data is too erratic for analysis during year.

Table 2. Volumes of water in lakes on the first day of each month during the three study years.

Month	Lake No. I 1961-1962	Lake No. I 1962-1963	Lake No. I 1963-1964	Lake No. II 1961-1962	Lake No. II 1962-1963	Lake No. II 1963-1964	Lake No. III 1961-1962	Lake No. III 1962-1963	Lake No. III 1963-1964	Lake No. IV 1961-1962	Lake No. IV 1962-1963	Lake No. IV 1963-1964	Lake No. V 1961-1962	Lake No. V 1962-1963	Lake No. V 1963-1964
Sept.	0.0	0.0	0.0	*	3.4	15.7	0.0	2.9	13.2	*	1.0	22.3	0.0	9.0	0.5
Oct.	0.0	0.0	0.0	*	1.7	4.5	0.0	0.0	10.4	*	0.0	13.5	0.0	0.0	0.0
Nov.	0.0	0.0	0.0	*	1.5	0.0	0.0	0.0	8.9	*	1.5	8.4	0.0	3.0	0.0
Dec.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.6	0.0	0.1	6.0	0.0	0.3	0.0
Jan.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.5	0.0	0.0	4.5	0.0	0.0	0.0
Feb.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	0.0	0.0	*	0.0	0.0	0.0
Mar.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6	0.0	0.0	*	0.0	0.0	0.0
Apr.	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	1.3	0.0	1.0	*	0.0	6.1	0.0
May	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	*	0.0	0.0	0.0
June	0.0	55.8	4.5	0.0	47.5	35.0	0.0	63.0	0.3	0.0	90.4	*	0.0	37.0	0.0
July	0.0	22.5	1.5	0.0	37.6	2.4	0.0	24.9	8.7	5.0	31.1	*	0.0	0.0	0.7
Aug.	0.0	5.0	0.0	9.8	38.2	0.0	3.8	16.9	5.1	16.3	15.2	*	38.2	0.0	0.0

Month	Lake No. VI 1961-1962	Lake No. VI 1962-1963	Lake No. VI 1963-1964	Lake No. VIII 1961-1962	Lake No. VIII 1962-1963	Lake No. VIII 1963-1964	Lake No. IX 1961-1962	Lake No. IX 1962-1963	Lake No. IX 1963-1964	Lake No. X 1961-1962	Lake No. X 1962-1963	Lake No. X 1963-1964	Lake No. XI 1961-1962	Lake No. XI 1962-1963	Lake No. XI 1963-1964
Sept.	0.0	0.0	0.0	*	9.9	5.0	*	4.8	0.0	*	0.0	0.0	*	*	28.4
Oct.	0.0	0.0	0.0	*	9.9	0.0	*	0.6	0.0	*	0.0	0.0	*	*	8.6
Nov.	0.0	0.0	0.0	*	5.1	0.0	*	0.0	0.0	*	0.0	0.0	*	*	0.0
Dec.	0.0	0.0	0.0	*	1.9	0.0	*	0.0	0.0	*	0.0	0.0	*	0.0	0.0
Jan.	0.0	0.0	0.0	*	0.0	0.0	*	0.0	0.0	*	0.0	0.0	*	0.0	0.0
Feb.	0.0	0.0	0.0	*	0.0	0.0	*	0.0	0.0	*	0.0	0.0	*	0.0	0.0
Mar.	0.0	0.0	0.0	*	0.0	0.0	*	0.0	0.0	*	0.0	0.0	*	0.0	0.0
Apr.	0.0	0.0	0.0	*	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	*	0.0	0.0
May	0.0	0.0	0.0	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	*	0.0	0.0
June	0.0	95.2	3.0	*	117.0	0.0	0.0	21.7	0.0	0.0	34.8	0.0	*	183.0	22.2
July	0.0	12.5	14.2	*	83.3	3.0	0.0	1.0	0.0	0.8	11.5	0.0	*	72.2	23.8
Aug.	4.4	0.0	8.8	*	54.5	2.3	0.0	0.0	0.0	3.5	0.0	0.0	*	36.0	3.7

* No records available
Underlined numbers indicate values after modification

MODIFICATION OF LAKES

During the study year 1962-63, modifications were completed on Lake No. III (Hufstedler), Lake No. IV (L.C.C.) and Lake No. V (Kitten). These modifications were described in detail in Progress Report No. 2 (pages 18-24). During the past study year 1963-64, modifications were completed on Lake No. VI (Holland) and Lake No. VIII (Burgett). Also, some additional modification work was done on Lake No. III (Hufstedler) and Lake No. V (Kitten).

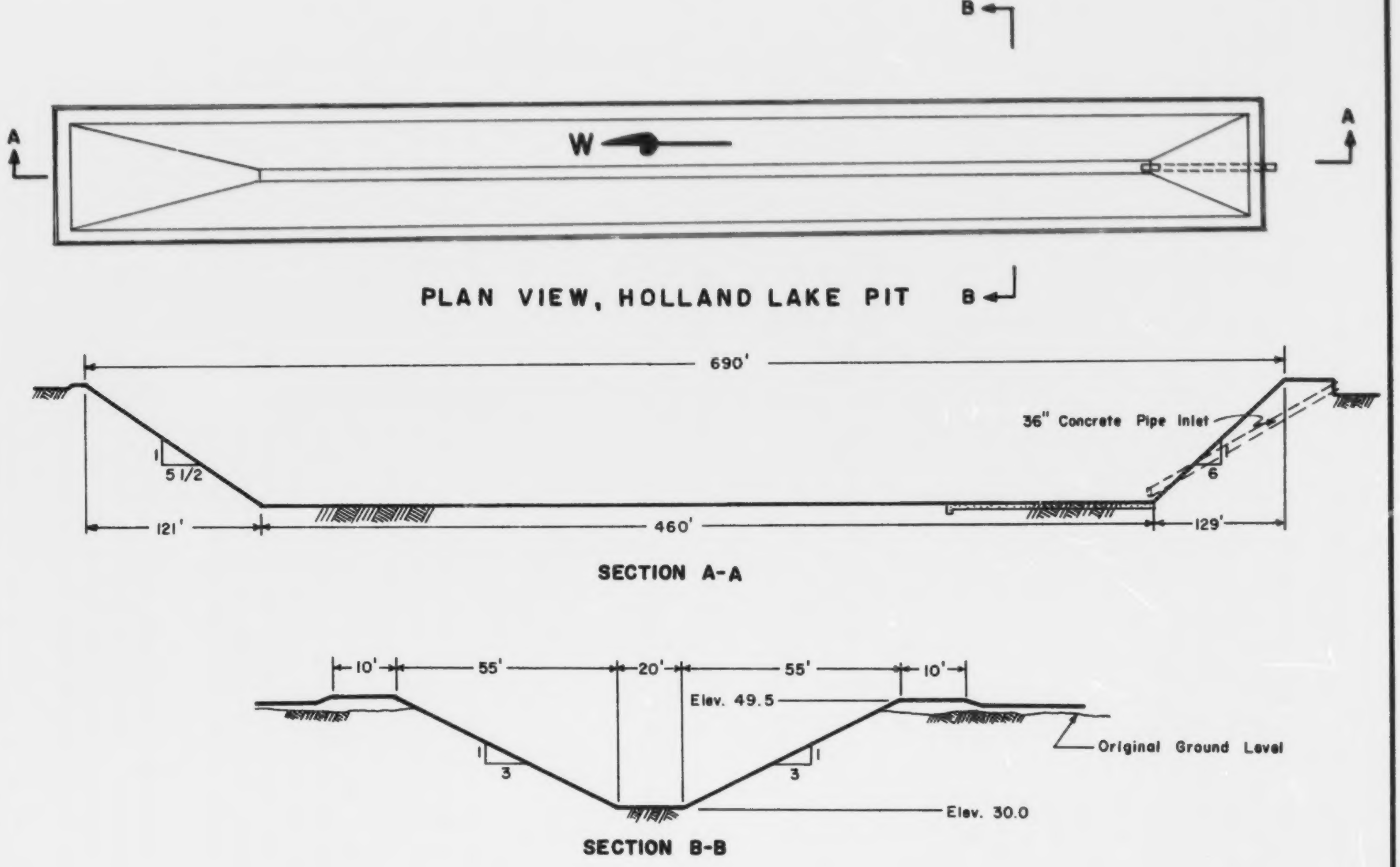
The modification of Lake No. VI (Holland) consisted of constructing a pit approximately 690 feet by 130 feet at the top, 460 feet by 20 feet at the bottom, and 17.0 feet deep. This pit was constructed with slide slopes of 3:1 and end slopes of 5 1/2:1 and 6:1 (See Figure 1). Approximately 21,800 cubic yards of dirt were removed from this pit and spread evenly onto the adjoining lake bottom. A dike was constructed around the pit and a 36-inch concrete pipe inlet was placed on the east side of the pit. All water entering the pit comes through the inlet. An aerial view and panoramic picture of the completed modification are shown in Figure 2.

This modification combined features indicated as desirable by the performance of previously altered lakes. These incorporated side slopes of 3:1, making the pit long and narrow and deep, and the use of a dike around the pit to make all water enter the pit at one point. Also, the necessity of some type of inlet structure has been shown. All these features were incorporated into the Lake No. VI (Holland) modification.

This pit, as constructed, holds 16.1 acre-feet of water with a surface area of 1.85 acres. This volume of water, prior to modification, covered 11 acres of land. The cost of the earthwork and 36-inch concrete pipe inlet at Lake No. VI (Holland) was $5,990.00.

The modification of Lake No. VIII (Burgett) was altogether different from the other modifications. A pit approximately 300 feet by 100 feet at the top, 170 feet by 15 feet at the bottom and 12.5 feet deep was excavated in the bottom of Lake No. VIII (Burgett). Instead of spreading the dirt evenly over the adjoining lake bottom, the dirt was used to construct a 7-foot earth fill dam across the middle of the lake. A diversion terrace was constructed around the west half of the lake in such a way as to direct all runoff water onto the east half of the lake where it is retained by the dam. An aerial view and panoramic view of this modification are shown in Figure 3. A sketch of the Burgett modification is shown in Figure 4. An emergency spillway was constructed on the north end of the dam to handle extremely large rains. A lake pump was installed at the lake and designed so that any water which overflows the pit can be pumped onto the farmer's land for use in irrigating crops. The pit has a capacity of 4.0 acre-feet, therefore pumpage from the lake is restricted to anything in excess of 4.0 acre-feet. Because of the restricted pumpage, fish have been stocked in this lake and experiments are being conducted to see if a fish population can be sustained in the lake.

This modification was chosen because more water storage could be created with less soil removal. The pits require an acre-foot of dirt to be moved to create an acre-foot of storage. With the dam across the lake, a larger water storage area was created with less excavation and fill. This design does not incorporate the small area



PLAN VIEW, HOLLAND LAKE PIT

SECTION A-A

SECTION B-B

A
B
W
B
A
690'
36" Concrete Pipe Inlet
1
5 1/2
6
121'
460'
129'
10'
55'
20'
55'
10'
Elev. 49.5
1
3
3
1
Original Ground Level
Elev. 30.0

Figure 1. Sketch Plans Of The Modification At Lake No. VI (Holland).

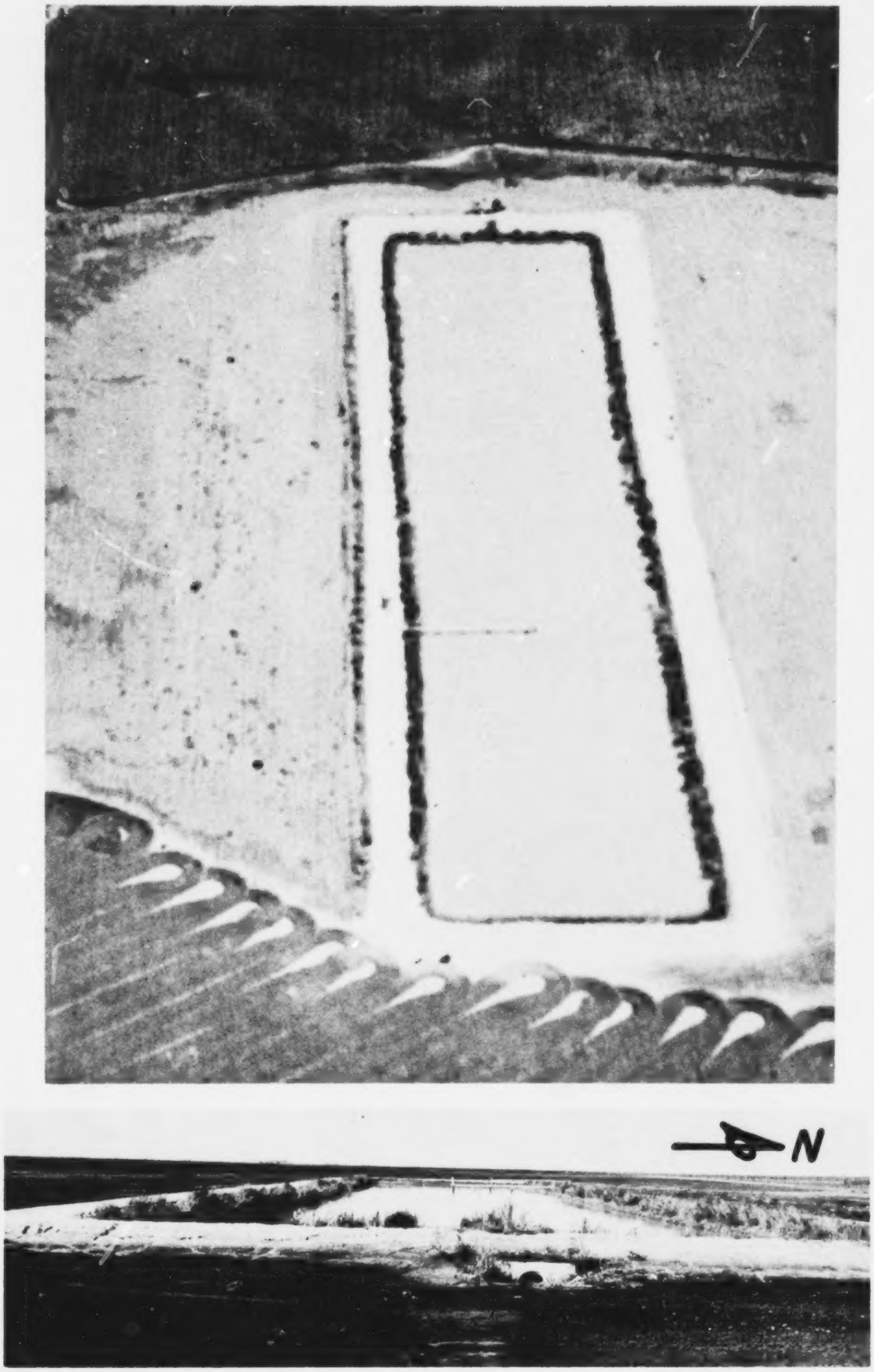


Figure 2. Aerial And Panoramic Views Of The Modification At Lake No. VI (Holland).

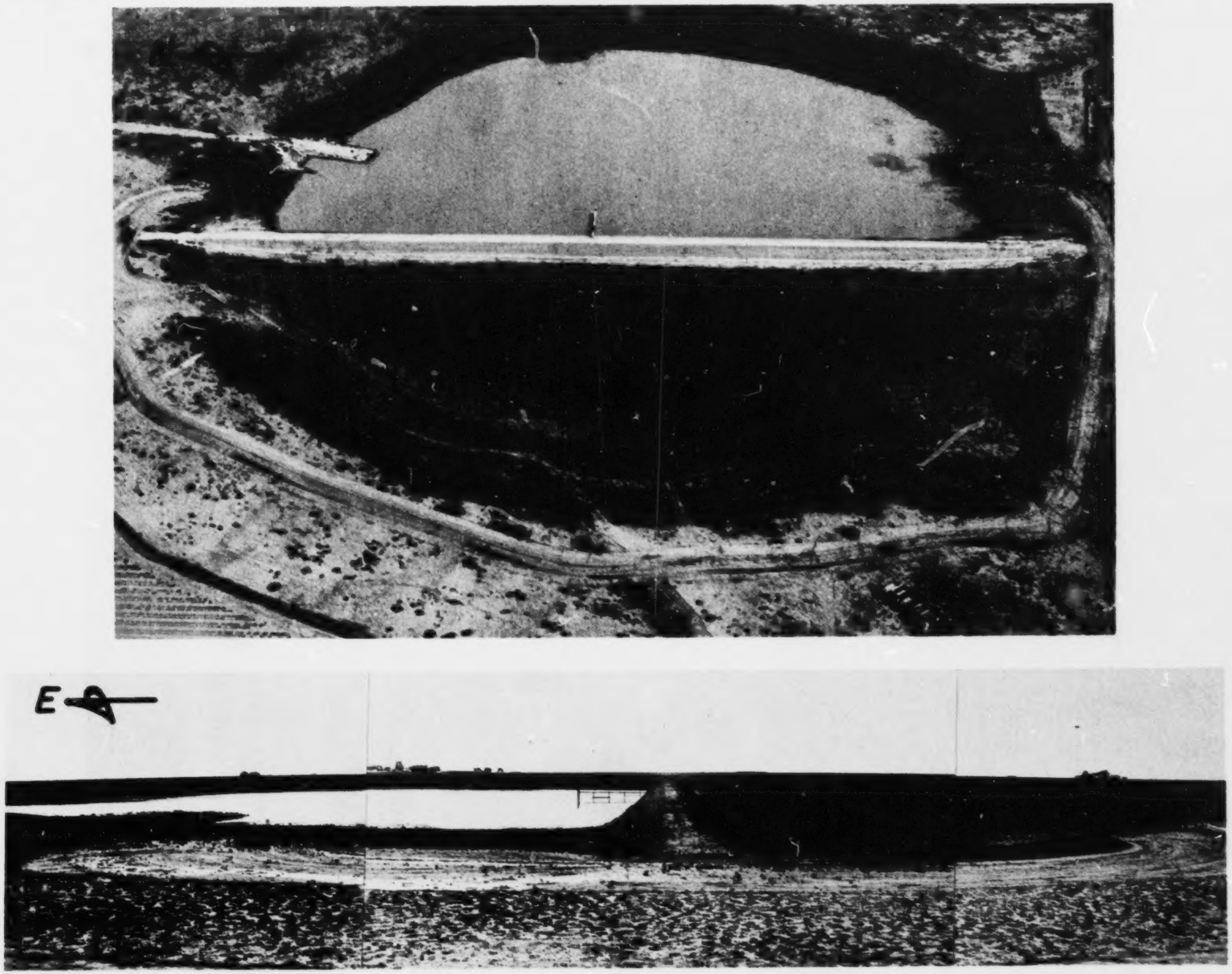


Figure 3. Aerial And Panoramic Views Of The Modification At Lake No. VIII (Burgett).

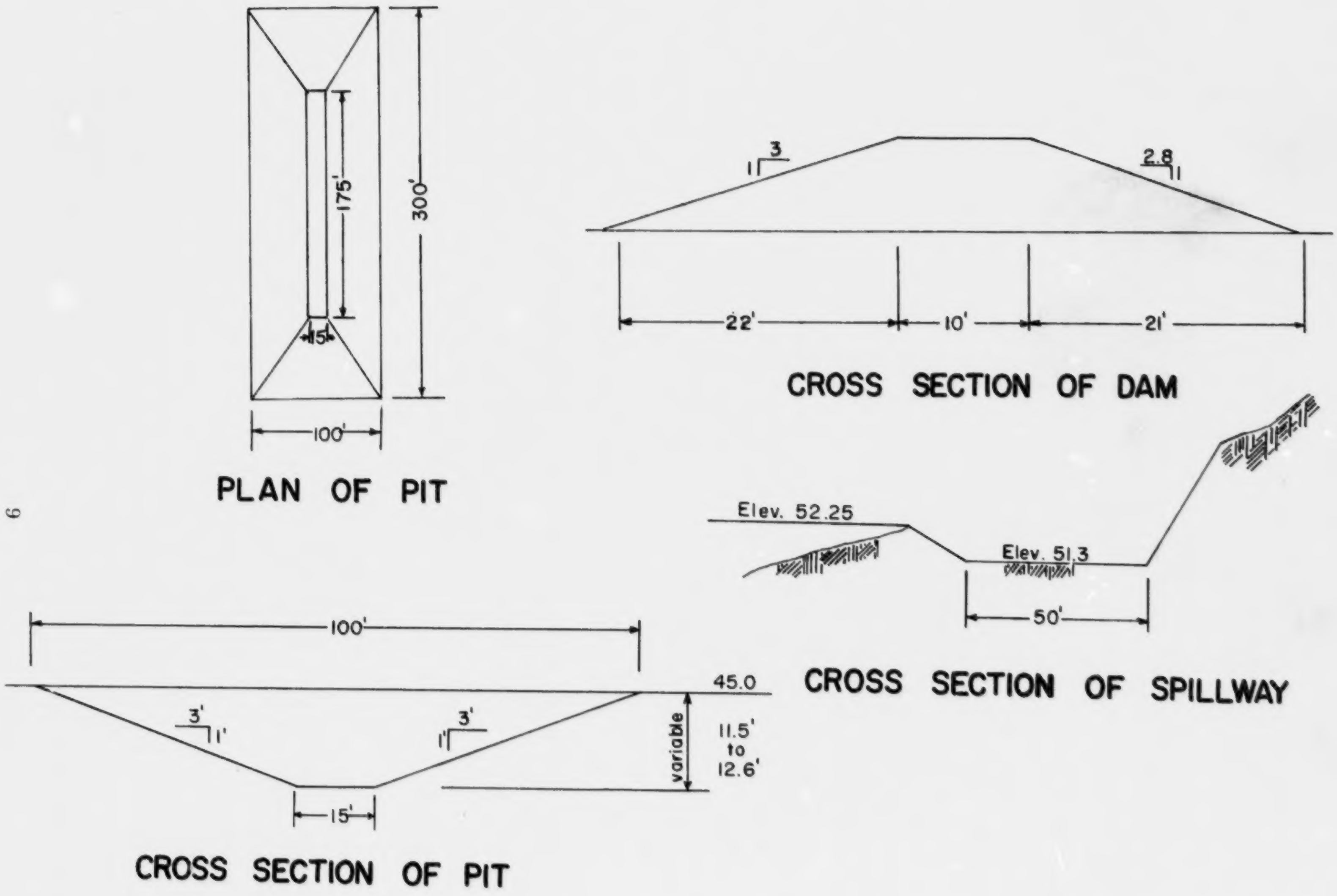

175'
300'
15'
100'
PLAN OF PIT
3
1
2.8
1
22'
10'
21'
CROSS SECTION OF DAM
Elev. 52.25
Elev. 51.3
50'
CROSS SECTION OF SPILLWAY
100'
45.0
3'
1'
3'
1'
variable
11.5' to 12.6'
15'
CROSS SECTION OF PIT

Figure 4. Sketch Plans of The Modification At Lake No. VIII (Burgett).

and deep water which the pits have and therefore, may not be as effective in reducing evaporation. However, there will be many instances when such a design will be preferred to the pit by individual landowners.

Since all of the water is restricted to the east side of this lake, a net land salvage of 8.1 acres has been realized. A fine rye crop is presently growing on this salvaged lake bottom and will provide grazing for cattle during the winter months. Construction costs for this modification totaled $3.790.00.

Additional construction was done on Lake No. III (Hufstedler) during the study year 1963-64. This consisted of removal of some soil along the top edge of the modification to build a dike around the modification. None of the soil was spread onto the lake bottom. This work created more storage space in the pit and also increased the surface area. All water presently is directed to the north end of the pit where it enters by way of a concrete spillway. The pit presently has a capacity of 26.3 acre-feet with a surface area of 3.6 acres. Without modification this volume of water would cover 15.1 acres of land. The cost of the additional modification and the concrete spillway amounted to $2,340.00. This, plus the $5.960.00 spent last year makes a total cost of $8,300.

Additional construction at Lake No. V (Kitten) consisted of building a concrete spillway on the east end of the pit. The cost of this work was $1,600.00. The cost of the pit constructed during early 1963 was $3,870.00. Therefore, the total cost of this modification is $5,470.00. Design plans for the concrete spillway at Lake No. V (Kitten), the concrete spillway at Lake No. III (Hufstedler), and the 36-inch concrete pipe inlet at Lake No. VI (Holland) are shown in Figures 5, 6 and 7 respectively.

MOSQUITO BIOLOGY AND ECOLOGY

In this investigation, major emphasis has been placed on the weekly estimation of numbers of mosquito larvae in each of the study lakes. Subsidiary studies have been conducted on the factors affecting the abundance and distribution of larvae within the playa. Preliminary investigations of the numbers and distribution of adult mosquitoes have been made using light traps on three of the study lakes and within the city of Lubbock. Laboratory studies on the establishment of colonies and length of the life cycle have been conducted.

Larval Production Studies

As in the past two years, lakes were sampled once a week, using a line transect design. This design consisted of placing a stake in the center of the bottom contour of the lake; transect lines then being marked off with stakes at 36 degree intervals around the center stake. On each sampling date, the sampler made his first dip with a one-half pint capacity, white enamel dipper at the edge of the water and continued along the transect line toward the center stake, sampling every 30 feet. As the sampler reached each dipping station, he stopped walking in order that the water might settle and allow the larvae to rise to the water surface. During this waiting period all pertinent items on the sampling form were completed. After this waiting period the sampler dipped, counted, and recorded the total number of larvae in his dipper, and distinguished the larvae as to instar. At each dipping station, water depth, total

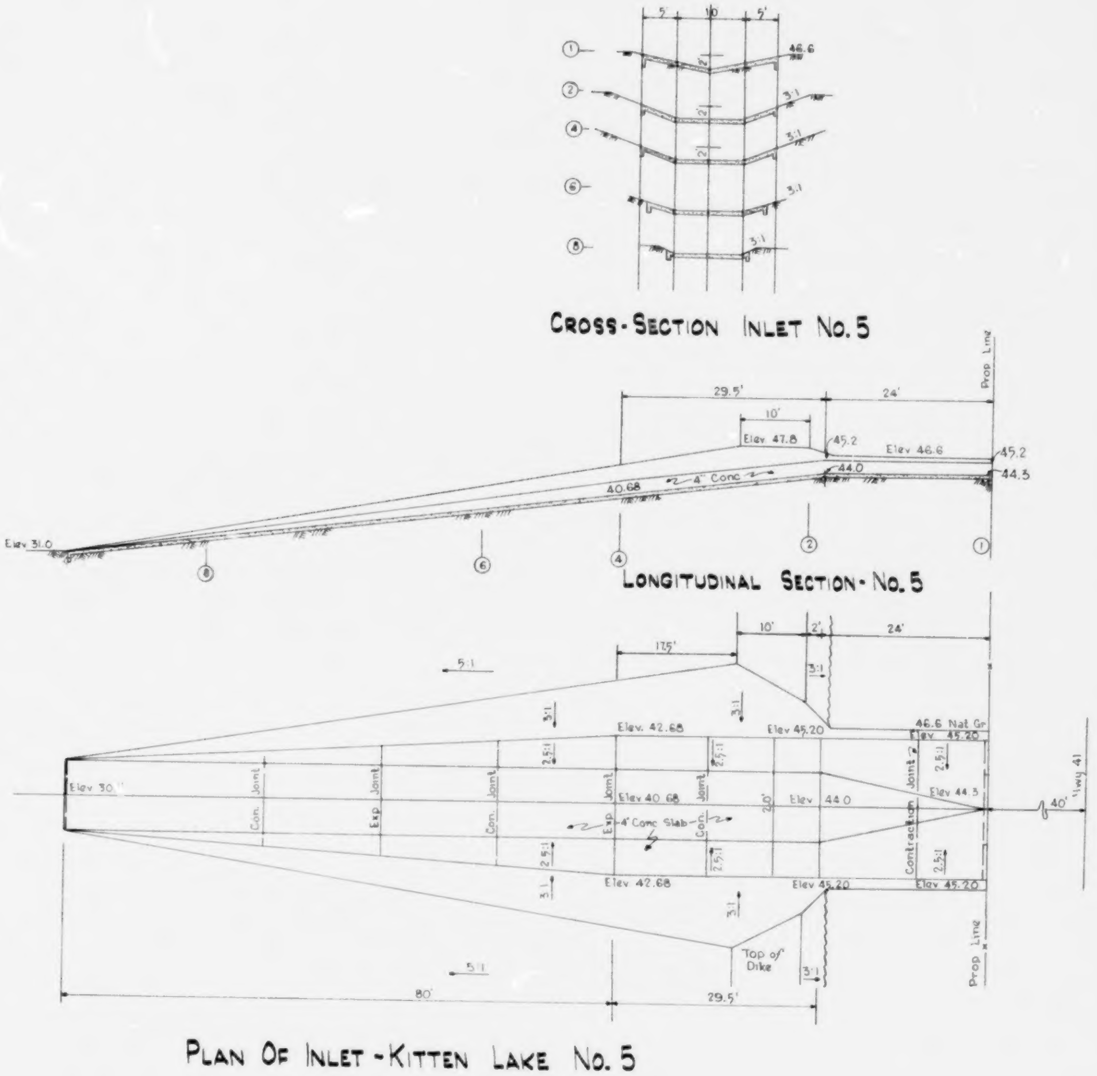
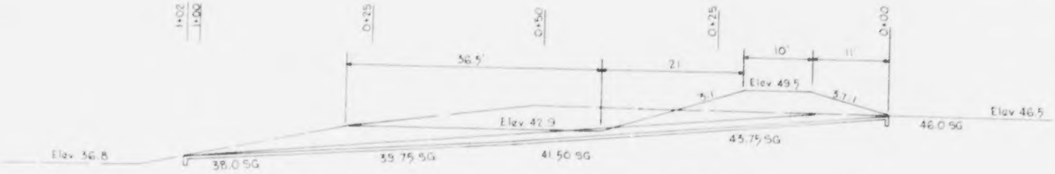
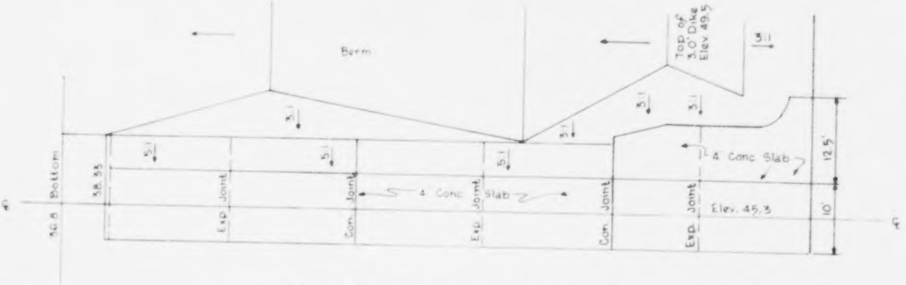

CROSS-SECTION INLET NO. 5
5'
10
5'
①
②
④
⑥
⑧
46.6
2'
3:1
LONGITUDINAL SECTION - NO. 5
29.5'
10'
24'
Prop Line
Elev 47.8
45.2
Elev 46.6
45.2
44.0
44.5
4" Conc
40.68
Elev 31.0
PLAN OF INLET - KITTEN LAKE NO. 5
17.5'
10'
2'
24'
5:1
3:1
2.5:1
Elev. 42.68
Elev 45.20
46.6 Nat Gr
Elev 45.20
Elev 30.
Con. Joint
Exp Joint
Con. Joint
Exp Joint
Con. Joint
Elev 40.68
4" Conc Slab
20'
Elev 44.0
Contraction Joint
Elev 44.3
40'
Hwy 41
Elev 42.68
Elev 45.20
Elev 45.20
Top of Dike
Prop Line
80'
29.5'

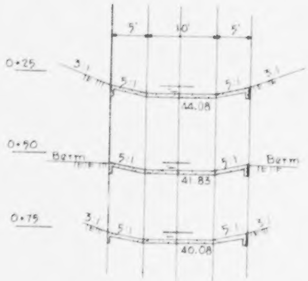
Figure 5. Sketch Plans of The Concrete Spillway At Lake No. V (Kitten).


1+02
1+00
0+25
0+50
0+25
0+00
36.5'
21
10'
11'
Elev 49.5
3:1
3:1
Elev 42.9
Elev 46.5
46.0 SG
Elev 36.8
38.0 SG
39.75 SG
41.50 SG
43.75 SG

LONGITUDINAL SECTION - LAKE NO. 3

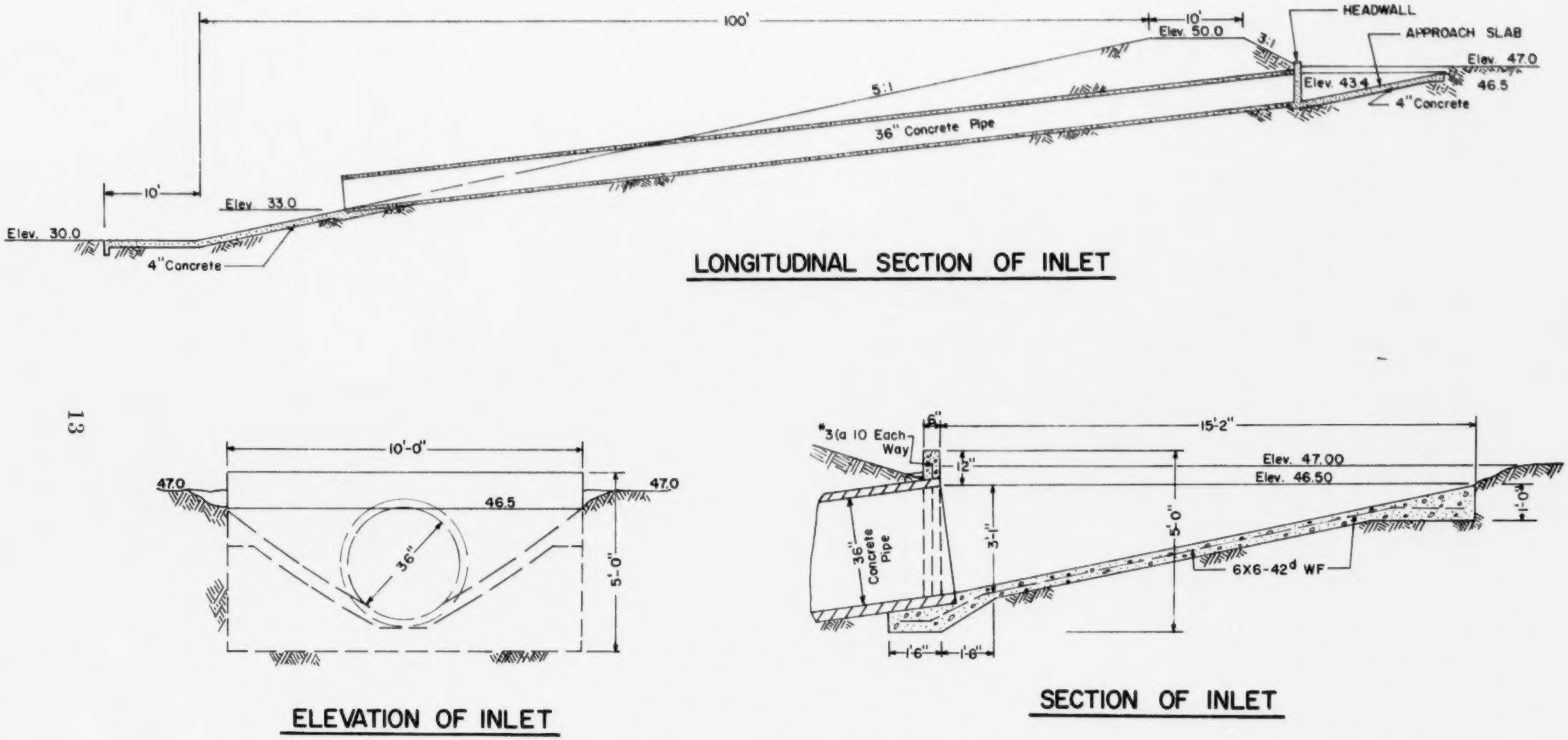

Berm
Top of 3.0' Dike Elev 49.5
3:1
3:1
3:1
3:1
5:1
5:1
5:1
4" Conc Slab
4" Conc Slab
12.5'
10'
Bottom
36.8
38.35
Exp. Joint
Con. Joint
Exp. Joint
Con. Joint
Exp. Joint
Elev. 45.3
℄
℄

HALF PLAN OF INLET - HUFSTEDLER LAKE NO. 3


5'
10'
5'
0+25
3:1
5:1
5:1
3:1
44.08
0+50
Berm
5:1
5:1
Berm
41.83
0+75
3:1
5:1
5:1
3:1
40.08

CROSS-SECTION - INLET NO. 3

Figure 6. Sketch Plans of The Concrete Spillway At Lake No. III (Hufstedler).


HEADWALL
APPROACH SLAB
100'
10'
Elev. 50.0
3:1
Elev. 47.0
46.5
Elev. 43.4
4" Concrete
5:1
36" Concrete Pipe
10'
Elev. 33.0
Elev. 30.0
4" Concrete
10'-0"
47.0
47.0
46.5
36"
5'-0"
#3 (a 10 Each Way
6"
15'-2"
12"
Elev. 47.00
Elev. 46.50
36" Concrete Pipe
3'-1"
5'-0"
1'-0"
6X6-42d WF
1'-6"
1'-6"

LONGITUDINAL SECTION OF INLET

ELEVATION OF INLET

SECTION OF INLET

Figure 7. Sketch Plans of The Concrete Pipe Inlet At Lake No. VI (Holland).

percent of the water surface covered by plants, percentage of broadleaf weeds, grass-like plants, and species composition of plants were recorded. Samples of the fourth instar larvae were returned to the laboratory for identification. The percent Culex tarsalis is presented in Appendix III, Table I. This appendix also presents the mean numbers of mosquito larvae per dip on each lake for each dipping date during the past three seasons. The graphs are presented simultaneously to aid in the comparison of mosquito production among all lakes, and during the three seasons on a given lake. Figures 1 -- 11A in Appendix III present the dipping data for the past three years from March through July. Figures 1 -- 11B in Appendix III present the dipping data from August through December for the past three years of study. The indices presented in Appendix III were determined by adding the values from the formula: (Average number of larvae per dip per contour) x (surface area in acres) for each contour to give the index value for a given lake on a given date. All of the study lakes have been mapped on one foot contour lines and the area represented by each contour has been calculated.

The average numbers of larvae per dip varied from zero to 22.1. The indices for total number of larvae varied from zero to 12.25, while the indices for fourth instar larvae varied from zero to 10.56. In presenting these data, separate graphs have been made showing the indiced or larval count-date relationships at the top of each graph with surface acres of water and the rainfall for all three years recorded below. These values are presented simultaneously to help establish and interpret possible inter-relationships of rainfall pattern and the inundation of the lake bed and consequent overwintering egg hatch and Culicine egg deposition.

The low mosquito production can be attributed to light scattered showers in May and June. The rains were slow-falling, and dry soils soaked up the moisture without much runoff. Lakes No. I (Huckabee), II (Knowles), XI (Krueger), and XII (Idalou), received varied amounts of water. Lake No. I (Huckabee) received very small amounts of water in May resulting in only a small hatch of floodwater species of mosquitoes; however, the water did not remain long enough for adult emergence to take place. This lake again caught runoff water in mid-June, allowing a hatch of floodwater species of mosquitoes. Water was impounded for about two weeks after which the lake went dry again and remained dry until mid-September when it again caught a small amount of runoff water. Aedes mosquitoes were found shortly after flooding occurred. This lake held water for only one week and mosquitoes were unable to reach the adult stage during this period of time due to low temperatures.

Lake No. II (Knowles) impounded a large quantity (77.9 acre feet) of runoff water from rains occurring May 15 and May 31. No mosquito production occurred throughout the year even though water was impounded until the third week of July. The absence of mosquito production can be attributed to the lack of emergent vegetation and deep water, both of which permitted heavy wave action.

Lake No. XI (Krueger) produced the most mosquitoes among lakes studied in 1964. This lake impounded a considerable amount of runoff water (53.2 acre feet) during the latter part of May and the first two weeks of June; however, at no time was the water deep enough to eliminate emergent vegetation. Smartweed (Polygonum lapthifolium) was abundant around the edge of the water, and an aquatic fern (Marsilea spp.) grew abundantly on the entire lake. Soon after the first flooding, Aedes mosquitoes were produced in this most ideal of microhabitats. However, no larvae were found in regular dipping along the transect lines. As the water line receded, vegetation became more dense, and mosquito production increased although Gambusia affinnis affinnis were being maintained in the lake as a biological control measure. Culex tarsalis production was quite heavy from mid-July until the lake became dry in mid-August. A large population of floodwater species of mosquitoes was produced following a hatch from runoff water on the 13th of September. At the time of the September inundation, the lake was almost completely covered by smartweed (Polygonum lapthifolium) and barnyard grass (Echinocholoa crusgalli) which provided much protection to emerging adult mosquitoes. The lake continued to be a heavy mosquito producer until it was completely dry on October 15, 1964.

A pit for year-long maintenance of minnows was constructed in a new lake, No. XII (Idalou) acquired during the winter of 1963-64. Rush (Eleochris spp.) offered protection to ovipositing females after inundation on May 16. As usual, there was an initial hatch of Aedes and Psorophora species soon after flooding occurred. Culex tarsalis were first found the last of June and increased in numbers until the lake became dry about the 21st of July. Although rains have fallen in the area since this time, no appreciable amount of run-off water has been impounded in this lake.

It should be noted that very few mosquitoes of the floodwater type were collected in samples taken early in the spring and summer. This may be attributed to the high water line of the previous fall. Rains in 1964 were not sufficient to fill the lakes to last year's level, so the eggs of the Aedes and Psorophora were not inundated and thus did not hatch. As the lakes were drying in mid-summer, sufficient numbers of floodwater mosquitoes were present to "seed" the bottom of the lake beds with eggs. The rains of September, although light, were enough to cause hatching of these recently-deposited eggs.

Studies are now being completed on the correlation between water depth, vegetative cover, species of plants and mosquito numbers. Correlation and regression analyses will be made from data derived from the study. Tests have also been conducted to determine dipping efficiency indices. The results of these studies will be presented later in the year as a supplement to this report.

As in 1963, the most significant findings concerning mosquito breeding in the study lakes is the complete suppression of mosquito breeding in modified playa sinks. While many statistical evaluations are not complete at this time, there is no doubt that the modifications have been completely successful for this criterion of their design.

Observations of Cultivation Effect on Mosquito Production

It is a common practice for farmers on the South Plains of Texas to raise crops on playas of small size, but most of the larger playas catch enough water through the spring and summer to inundate and kill crops or make weed control very difficult.

When a playa that is left undisturbed for several years, as Lake No. V (Kitten, Lake No. X (Reese) and Lake No. VIII (Burgett), a heavy mast growth of vegetation soon dominates the bottom. This vegetation provides the habitat for numerous organisms, and of primary public health importance are the mosquitoes produced when water covers the bottom of the playa. As the soils dry after the water has evaporated, transpired or percolated through soil, the montmorillonite clay shrinks and large cracks form in the lake bed. When subsequent rains put more water in the lakes, these cracks will slough off, and form depressions or "pot holes" that become wider and deeper. Some of these reach two feet in diameter unless the soil is plowed or silting after a big rain covers up the area. Since these holes become the residual site of water after the main bottom of the playa has gone dry, a habitat for mosquitoes and other insects of economic and public health importance is provided. Dipping records for the past three seasons show that Burgett, Reese and Kitten Lakes do produce mosquitoes under average rainfall conditions, and vegetation has been very abundant at times of peak mosquito production. The female mosquitoes of the *Aedes* and *Psorophora* genera are known to oviposit on the surface of the moist soil at the edge of the lake water, or at the depressions mentioned above and thus extend mosquito production beyond that provided by regular impoundment. Two lakes, Lake No. VI (Holland) and Lake No. III (Hufstedler), that provide differing habitat conditions, were studied along with the three lakes mentioned. They were plowed several times during each study year to control weeds and decrease blowing dust. Lake No. VI (Holland) and Lake No. I (Huckabee) have caught runn-off water every year of the study, with the exception of Lake No. I (Huckabee) in 1961. While other study lakes were heavy producers until they went dry, these two lakes produced only a few mosquito larvae and at no time were they found to have a large hatch of mosquitoes. On the plowed lakes the cover recorded on any transect was normally from zero to 3%, compared to 15% to 90% cover on the unplowed lakes. Also, the bed of the plowed playa was void of "pot holes". Many of the playas of the South Plains of Texas are very shallow, small in area, and have such small watersheds, that the farmer does not usually lose crops from flooding. Where crops are cultivated and weeds are controlled in these lakes, mosquito production is insignificant according to records kept by field men of the Lubbock City-County Health Department.

Light Trap Studies

New Jersey light traps were installed on three study lake sites--Lake No. X (Dupree), Lake No. IV (L.C.C.) and Lake No. V (Kitten). Lake No. X (Dupree) and the unmodified side of Lake No. V (Kitten) both caught sufficient run-off to fill small pot holes in the lake beds. These potholes, which averaged about twelve inches in diameter, produced many flood water mosquito larvae. Lake No. IV (L.C.C.) did not produce mosquito larvae.

Light traps on these lakes were located at distances of seven to sixteen miles apart. Insects from these light traps were collected twice weekly, and the mosquitoes identified as to genus. The average numbers of mosquitoes per light trap night on each lake are shown in Figure 8A. Species composition of adult mosquito numbers varied throughout the summer at all light trap stations. Since there were no mosquitoes produced in the lakes at times when mosquitoes were found in light traps, there must be places other than lakes which produce mosquitoes. Artificial water containers such as livestock watering troughs, discarded tires, and irrigation risers may all contribute significantly to mosquito production, especially in drier years. See Table 3 for results of the 1964 light trap studies.

A five year summary of species composition of adult mosquitoes collected by twelve New Jersey light traps located within the city of Lubbock were made available by the Lubbock City-County Health Unit. The data are presented semi-logarithmatically

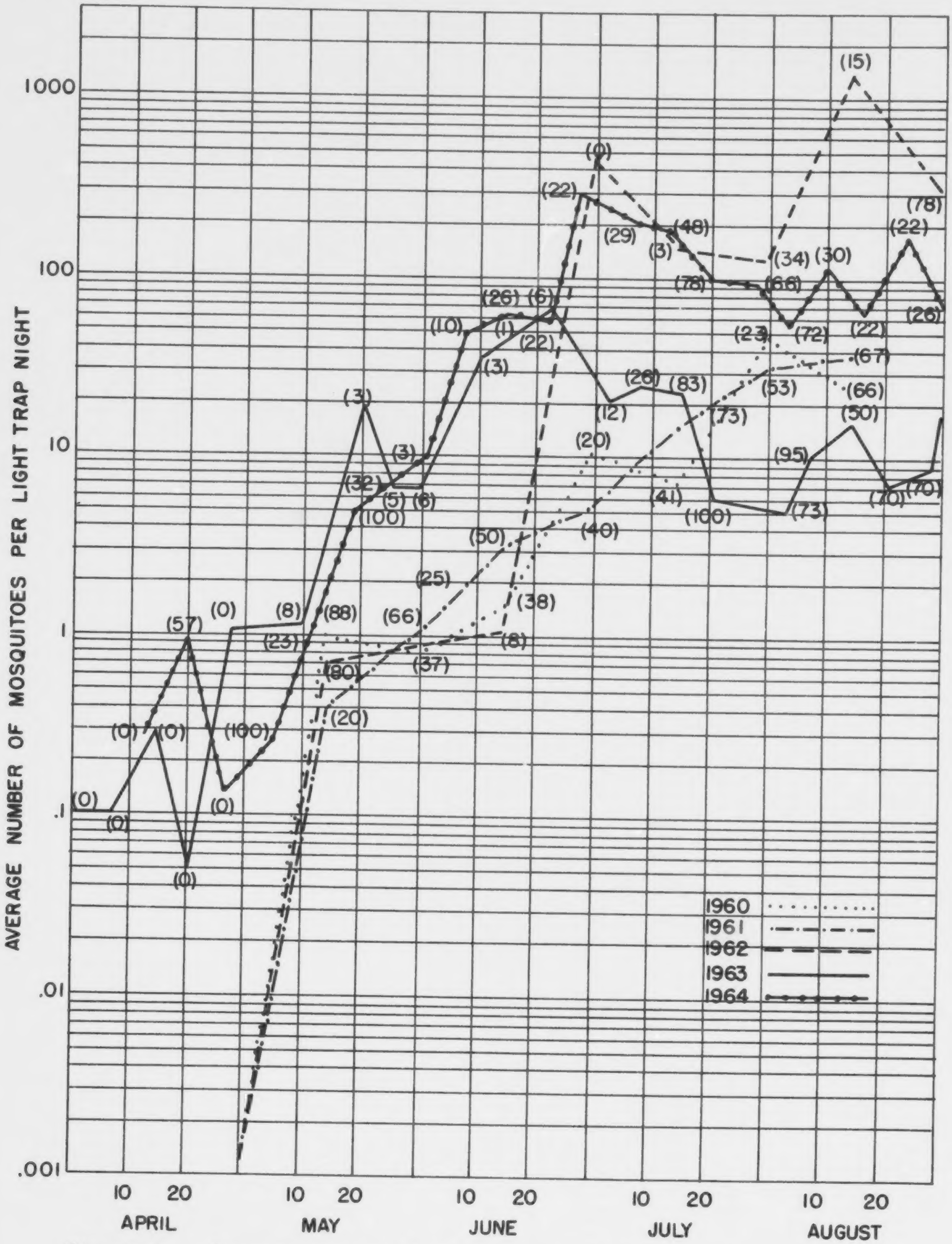


Figure 8A Average Number of Mosquitoes Per Light Trap Night Presented Semi-logarithmically for Traps Located within the City of Lubbock Figures in () Indicate % of total Catch that was Culex Tarsalis. 1960 through 1964. Lubbock, Texas.

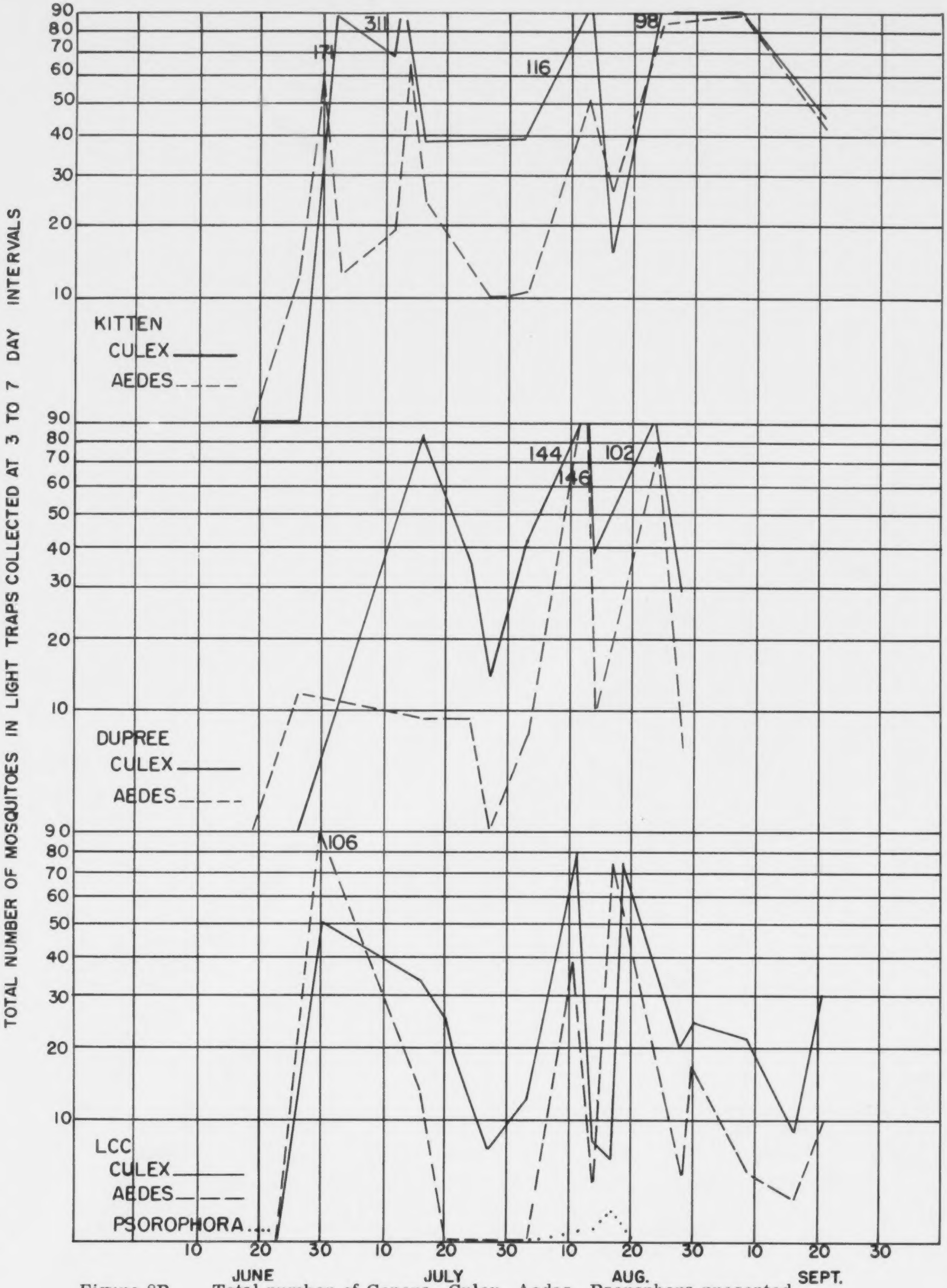


Figure 8B Total number of Genera, Culex, Aedes, Psorophora presented semi-logarithmically.

in Figure 8B. These data illustrate the seasonal pattern of population trends existing in this area. There is a continual increase in mosquitoes from June to September with a corresponding increase in the percent culex tarsalis.

Table 3. Total number of three genera Culex, Aedes, Psorophora mosquitoes collected in light traps at Dupree, Kitten, and LCC lakes and presented semilogarithmically on the next page, with the number of each genera presented below. 1964. Lubbock County, Texas.

Kitten's lake Light Trap Material, Lubbock County, Texas. 1964

Dates	6-26	6-30	7-3	7-11	7-14	7-16	7-27	8-3	8-13	8-17	8-25	9-8	9-21
Culex	-	-	171	68	311	38	39	30	116	16	98	90	45
Aedes	12	59	13	19	64	26	10	11	51	27	83	91	42

Dupree Lake; Light Trap Material. Lubbock County, Texas. 1964

Dates	6-26	7-16	7-24	7-27	8-3	8-11	8-14	8-24	8-28	8-31	9-9	9-21
Culex	-	84	35	14	41	144	38	102	28	38	29	43
Aedes	12	9	9	-	7	146	10	83	6	9	19	18

LCC Lake; Light Trap Material. Lubbock County, Texas. 1964

Dates	6-30	7-16	7-20	7-21	7-27	8-3	8-11	8-14	8-17	8-21	8-28	8-31	9-9	9-16-2
Culex	51	34	26	20	7	13	81	8	6	76	21	25	22	9 31
Aedes	106	14	-	-	-	-	38	4	75	33	5	17	5	3 10
Psorophora-		-	-	-	-	-	-	1	2	-	-	-	-	- -

Laboratory Culture Data

Cultures of *Culex quinquefasciatus* have been maintained in the Tech laboratory for three seasons. Cultures of *Culiseta inornata* and *Culex tarsalis* could not be established, presumably due to the inability to adequately control humidity and temperature in the insectory. However, life cycles for *C. tarsalis* have been partially worked out and those for *C. quinquefasciatus* are complete for this laboratory.

The *C. quinquefasciatus* colony is maintained in a wire mesh cage 2x2x2 feet. Adults were maintained on sugar water, and blood from small chicks placed in the cage. Chicks were left only two hours daily as longer exposures proved fatal to the chicks. Water for oviposition was provided in enamel 8"x8" pans.

Egg rafts were removed daily and placed in rearing pans measuring 8"x10"x1.5". Upon hatching, which occurred at a mean time of 20.5 hours after ovoposition, larvae were placed in other rearing pans at a rate of approximately 500 larvae per pan. At the time of transfer, the larvae were fed by placing a generous quantity of high protein commercial chicken feed pellets in the rearing pans. No yeast or liver powder was added to the diet. Food was added daily in quantities sufficient to keep the water slightly cloudy but not enough to cause scum. The larval stage was completed in 8 to 10 days with pupation almost totally complete on the tenth day.

Adult emergence occurred in approximately 50 hours. Pupae were removed from rearing pans and placed in the adult rearing cage where they were allowed to emerge. Most females fed readily upon chicks on the third day after emergence, and egg rafts were found seven days after emergence. Maximum egg production occurred ten days after emergence of the adults.

Observations of *C. tarsalis* mosquitoes indicate that its life cycle is very much like that of *C. quinquefasciatus*; however, because of failure to maintain a *C. tarsalis* colony, more work needs to be done before this general observation is substantiated.

WILDLIFE OBSERVATIONS

Various species of wildlife are attracted to the aquatic habitat created by the playa lake. The waters of the playa lake offer food and protection to the wildlife inhabiting the area.

Birds

Shovellers (*Spatula clypeata*) and mallards (*Anas platyrhynchos*) were observed on Lake No. IV (LCC) and Lake No. III (Hufstedler) during the winter of 1963-64. In the spring, large numbers of pintails were observed on several of the lakes that impounded water. As the water level receded in the summer months, the number of shore birds increased until the lake water disappeared. Tree swallows and black terns were observed feeding around the study lakes during the spring months. Observations were made of several species of unidentified sandpipers, plovers, crane, phalaropes, avocets and stilts. Several species of blackbirds, sparrows and hawks were seen in the immediate watershed of the lake. There does not seem to be any observable change in numbers of fowl, nor in the numbers of species found the past three seasons.

Amphibians and Reptiles

With the onset of the spring rains, a large population of spade-foot toads (Scaphiopus) was observed. Both the leopard frog (Rana pipiens) and the spotted frog (Pseudacris clarki) were observed on both modified and unmodified lakes.

The modified lakes that have retained water throughout the year have provided a stable aquatic habitat for turtles, salamanders, frogs and other aquatic organisms that previously had to burrow in the mud of the drying lake bed to survive.

Fish Studies

On July 23 of this year, large mouth bass and bluegill sunfish fingerlings were stocked from the U. S. Fish Hatcher at Dexter, New Mexico into four modified lakes; Lake No. VIII (Burgett), Lake No. VI (Holland), a sewage lagoon at a privately modified lake at Texas Tech, and Petersburg, Texas. Channel catfish fingerlings were added to these same lakes on September 27, 1964. Fifty fish of each species were added per surface acre of water. Growth rates of these fish will be studied.

NET PLANKTON POPULATION TRENDS

Population counts from weekly sampling of net plankton populations are presented in semi-logarithmical form in Figures 13-23, Appendix III. The plotted figures are mean counts of duplicate lots on each sampling date. Counts were adjusted by mathematical computations to give the average numbers of net plankters per liter of original lake water. Only those plankters large enough to be caught by the 125 mesh net were counted.

When referring to the population charts, it is important to note the lake identification key given in the first page of Appendix III. Of these lakes, the net plankton populations of the unmodified playa lakes were obtained from Lake No. IV, (LCC), 1962; Lake No. V (Kitten), 1962; and Lake No. X (Reese), 1962 and 1963. Plankton populations from modified playa lakes were obtained from Lake No. IV (LCC), 1963; and Lake No. III (Hufstedler), 1963.

Examination of total net plankton numbers plotted in Figure 13 (Appendix III) readily showed that the modified playa lakes had smaller numbers of all plankters encountered. On only two sampling dates were plankton numbers higher in modified lakes than on unmodified lakes. Although plankton numbers per sampling date were lower in the modified lakes, when the permanency of this body of water is compared to the intermittent nature of the unmodified playa lake, the total biomass produced over an extended period could well be above that of the unmodified lake. Of the water chemistry factors studied, alkalinity could well be the factor responsible for the low plankton population levels. Another feature that could be playing an important part in plankton reduction is turbidity. Light penetration in the shallow waters of the unmodified playa may be an insignificant problem, but with the increased water depth in the modified playa, turbidity could well be an important inhibiting factor. Most major plankton groups seem to follow much the same patterns in modified lakes as they do in the unmodified lakes, with the exception that, in modified playas, smaller fluctuations occur due to permanency, and populations are generally lower.

MAINTENANCE OF RESIDENT POPULATIONS OF GAMBUSIA AFFINNIS AFFINNIS IN PLAYA LAKES

Biological control of mosquitoes was investigated again in 1964 using the mosquito minnow Gambusia affinnis affinnis as a predator. In the past, maintenance of minnow populations in playa lakes has been restricted by the intermittent nature of the playas. Observations also indicated that concentration and crowding of aquatic life as the lakes dried up created very difficult survival conditions for Gambusia. It was therefore deemed advisable to locate a pit somewhat lateral to the lake bottom to collect a smaller number of minnows and isolate them from receding water before final concentrations in the lake bottom had occurred. As the water level receded, only a part of the population was trapped.

One such pit was constructed in 1963 in Lake XI (Krueger). The pit maintained Gambusia through November 1963, at which time investigators estimated the total minnow population in the pit at 2,000. The pit was again sampled in February 1964, at which time no minnows were found; however, a large population of tiger salamanders (Ambystoma tigrinum) was found. Subsequent laboratory tests showed that this salamander will eat minnows if confined to a small area. It should also be noted that the pond was frozen during the late fall of 1963 and oxygen deficiency at this time might also have contributed to the fish kill. A large number of diving ducks was observed using this small pit, and may have been an important depletion factor. The pit did not hold sufficient water to carry fish throughout the dry season; it was completely dry by May 1, 1964, but the minnow population had reached extinction prior to loss of the habitat.

During the winter months of 1963-64, three additional lakes were modified by digging pits in them. These differed from the previously mentioned one in that the fill from the pit was used to form a berm around the pit. One major spillway was placed in the berm with its opening facing the high side of the playa. This modification of the original plan was made in an attempt to reduce silting and to decrease evaporation losses.

During the spring rains, only one of the newly-modified lakes, No. XII, (Idalou) caught water. On May 22 through 28th, minnows were put into the pit at Lake No. XII (Idalou) and re-introduced into Lake No. XI. (Krueger). As the season progressed, large numbers of minnows were observed in both lakes. It was noted that, although small minnows worked the edge of the lakes very well, mosquito populations continued to increase in both lakes as long as they held water. As the lakes dried in the latter part of July and during the first week of August, large numbers of minnows were trapped by the two pits. By October 30, Lake No. XII (Idalou) had not impounded additional water, however Lake No. XI (Krueger) caught enough run-off in September to inundate the pit area and release the minnows into the larger lake area. It was during this period of inundation that mosquito production reached its peak. During this hatch, floodwater species predominated, however, a few Culex tarsalis larvae were found before the water completely receded.

VEGETATION STUDIES AND OBSERVATIONS

With varying amounts of rain accumulating in those playa lakes studied in past years, it has been found that vegetation varied from nearly no cover when the water was over four feet deep, to practically 100% cover on a study lake bed after intermittent rains put small quantities of water in lakes. Such rains provided adequate moisture for plants to grow abundantly. *C. tarsalis*, *C. quinquefasciatus*, *Aedes vexans*, *Aedes solicitans*, *Psorophora spp.*were observed to increase as vegetative cover increased.

Smartweed (*Polygonum lapthifolium*), rush (*Eleochris*), barnyard grass (*Echinocholoa crusgalli*), pigweed (*Amaranthus spp.*), and arrowhead (*Sagitaria lonbiloba*) were the most numerous forms of vegetation observed in the study lakes.

Twenty-four one-yard square plots were established on three lakes: Lake No. VI (Holland), Lake No. III (Hufstedler), and Lake No. IV (LCC). The plots were located on the established transects used for sampling mosquito population. Vegetation was counted once a month in all the plots that were not inundated. Table No. 3 (Appendix III) shows the numbers of plants of each species on each observation date.

Barnyard grass, smartweed and pigweed were the most abundant plants growing on most of the lake beds. *Marsilia spp.* was plentiful on Lake No. XI (Krueger) during the summer when water was high, however, as the water line receded, smartweed and barnyard grass became the more abundant species.

Lake No. III (Hufstedler) and Lake No. IV (LCC) showed an increase in numbers of plants and the variety of species present in their second year of modification. Smartweed has grown most abundantly on Lake No. IV (LCC) this year. Pigweed was the second most abundant weed. Lake No. V (Kitten) modification, also finished in the spring of 1963, had pigweed growing predominantly around its edge and in the bottom of the pit. The fill area of Lake No. V (Kitten) was planted in grain sorghum and cultivated during the summer months of 1964.

Lake No. VIII (Burgett) and Lake No. VI (Holland) were modified in 1964 and spring rains filled both to their pit capacity. Fall rains spread the water over the fill area of Lake No. VI (Holland) and into the old lake bed of Lake No. VIII (Burgett). Lake No. VIII (Burgett) had a cover of *Helianthus ciliatus* or blue weed over most of the lake bed throughout the summer. In previous years, smartweed, arrowhead, and other aquatic plants have dominated this lake; however, because of the pit construction and the diversion terrace, all the lake's watershed runn-off was impounded in the smaller area. *Helianthus ciliatus* dominated the species composition in the dry lake bed.

Lake No VI (Holland) has been deep-plowed each summer in previous years when the lake bed dried. This practice prevented aquatic vegetation from becoming established and producing seed. Pigweed has been the predominant plant under these conditions, both before and after modification. The successional pattern of re-vegetation of the modified pits is definitely toward a habitat suitable for mosquito production, but present indications are that the area suitable for mosquito production will be limited to a narrow peripheral band only a few feet in width, as compared to many acres in unmodified areas.

HYDROLOGY DATA

Lake No. VI (Holland) and Lake No. VIII (Burgett) were modified during 1963-1964, necessitating the resurveying and the calculation of their new area and volume characteristics. Lake No. III (Hufstedler), although modified last year, had some additional modification work done this year. Therefore, a new topographic map was prepared for this lake. The new maps (after modification) as well as the old maps (before modification) are presented in Appendix I.

The volumetric formulae, with modifications, for the wedge and obelisk were used in conjunction with the end-area formula to determine the volumetric characteristics of each of the modified lakes. This information was then used to construct elevation-volume and elevation-area curves for each of the newly modified lakes. The new rating curves (after modification) along with the original rating curves (before modification) are shown in Appendix I.

Rainfall at each of the study lakes is measured in rain gauges which consist of a 5/8-inch glass tube set in a 5 3/4-inch graduated metal container (see Figure 9). These gauges are non-recording and require frequent field inspection. All lakes are presently visited at least once per week. In addition, an attempt is made to visit each lake after each major storm. Consequently, the recorded time of rainfall occurrence may contain errors; but, the recorded amounts of rainfall are assumed to be in the correct order of magnitude. Rainfall records at each of the study lakes are presented as histograms on the even-numbered figures in Appendix II.

A Leupold Stevens A-35 automatic water level recorder and a tilting bucket rain gauge were purchased in the fall of 1963. This recorder was placed in operation at Lake No. VI. (Holland) in the spring of 1964. The recorder and rain gauge combination will provide for a more accurate measurement of both the intensity and duration of rainfall along with the resultant changes in lake water level. The A-35 recorder is adaptable to a number of different time and gauge scales. Because the original time scale was too small, an overlapping on the rainfull intensity and duration chart was obtained. As a result, no rainfall intensity data were obtained. This situation has been corrected by using a faster time scale.

To determine the daily lake water levels, a system of staff gauges and automatic water level recorders is used. Staff gauges of the type shown in Figure 10 have been installed in all study lakes. These staff gauges, for the most part, require optical magnification for reading. Trash, mud staining, and algal growth render them difficult to read.

Because the staff gauges are non-recording, automatic water level recorders, such as the one shown in Figure 11, are highly desirable on a project such as this. At the onset of this study, the Texas Water Commission loaned five automatic water level recorders to the project. During the fall of 1963, six additional recorders, including the A-35 previously mentioned, were purchased by the Project. At the present time each study lake is being serviced by an automatic water level recorder.

In order for the water level recorders to function properly, a stilling well or recorder tower is necessary. Recorder towers such as those shown in Figure 12 have been installed at each lake. All recorder towers are, with slight modifications identical in design and construction to those towers described in the First Annual Progress Report (pages 30-32) and the Second Annual Progress Report (pages 8-14).

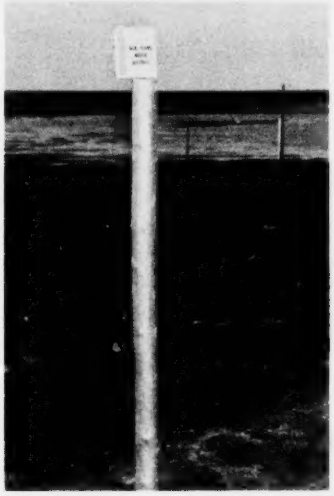


Figure 9. Glass Tubed Rain Gauge Used To Collect Rainfall Data.

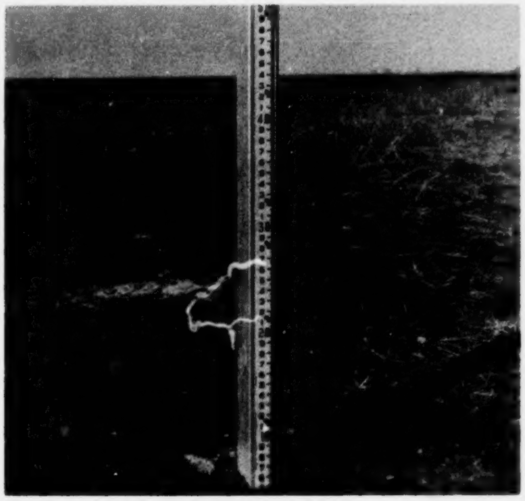


Figure 10. Typical Staff Gauge Installation At A Playa Lake.

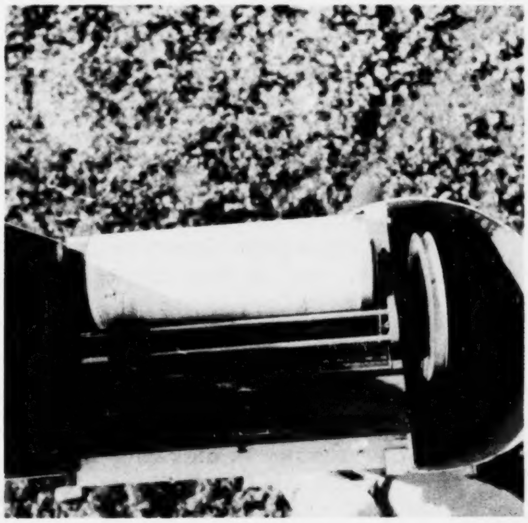


Figure 11. Automatic Water Level Recorder Installed Atop the Stilling Well.

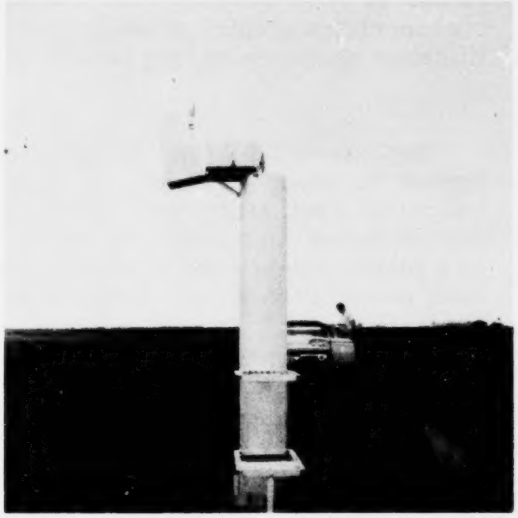


Figure 12. Recorder Tower Installed In A Dry Playa Lake. Note The Automatic Recorder At The Top Of The Tower.

RELATIONSHIP BETWEEN LAKE SOILS AND INFILTRATION

Infiltration

In the past, most people have generally agreed that the soils in playa lakes were relatively impermeable, and therefore little water was lost by percolation. However, during the two previous years of this study the lakes under study have lost large amounts of water rapidly. The volumes of water being lost from the lakes were much more than could be accounted for by evaporation. Therefore, it was thought that the amount of water lost to percolation was much greater than heretofore suspected.

To throw additional light on this supject, a series of infiltration tests and soil tests were conducted at Lake No. VI (Holland) during the summer of 1964. A double ring infiltrometer was employed in this test because of the minimum amount of water required, and because the infiltrometer can be stored and easily transported to various test locations.

Two metal cylinders of 8-inch and 16-inch diameters, and 17 inches long, were used to make up the double ring infiltrometer. Two cylinders are used so as to provide a buffer area that will insure vertical movement of the water through the soil profile. The infiltrometer ring was connected to a metal infiltration tank by means of a rubber hose. The tank provided a continuous water supply to the ring. The depth of water in the infiltrometer ring was held constant at approximately 8 inches by means of a float and valve arrangement. The decline of the water level in the metal tank was measured by a hook gauge which was accurate to 0. 00083 feet. The buffer ring was connected in a similar manner to a 55-gallon barrel. This arrangement allowed infiltration studies over long periods of time.

Because of the length of time involved in these infiltration tests, evaporation became an important factor. To measure the evaporation, another infiltration tank and double ring infiltrometer were constructed exactly like the first with the exception that the bottom was sealed on the infiltrometer. This eliminated percolation and allowed a measurement of evaporation alone. Figures 13, 14, 15, and 16 show the equipment in operation on an infiltration test.

The first infiltration test site at Lake No. VI (Holland) was approximately in the middle of the lake at an assigned elevation of 45. 0 feet. Each succeeding test was moved outward toward the south edge of the lake at 1 foot increases in elevation up to and including the 49. 0 foot elevation. The lake was later modified with a 20-foot deep pit. An infiltration test was then run in the bottom of the pit. Each of the infiltration tests were for a 100 hour duration except for the test at elevation 46. 0 which was for a 90-hour duration. The results of the tests are shown in Table 4.

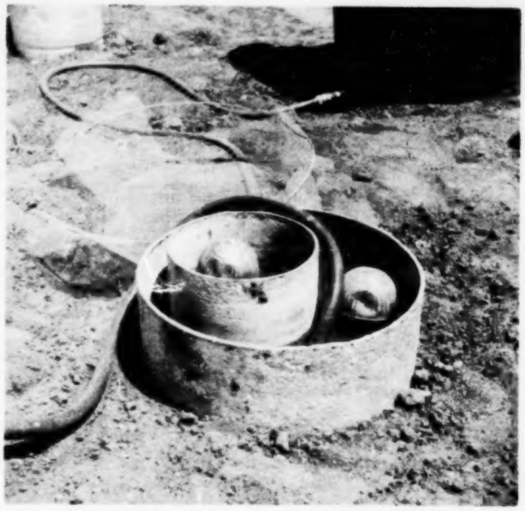


Figure 13. Double Ring Infiltrometer With Hose And Floats Attached.

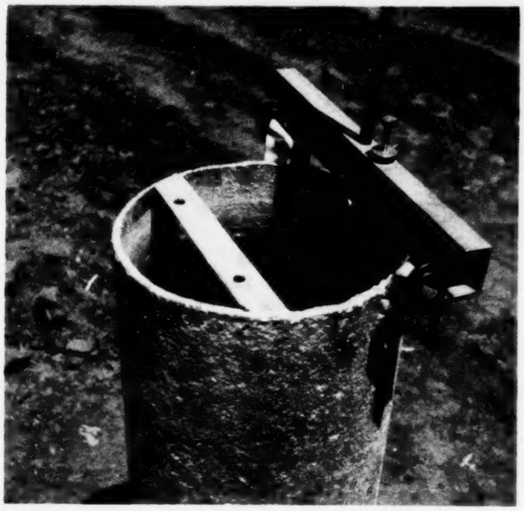


Figure 14. Infiltration Tank With Hook Gauge Attached.

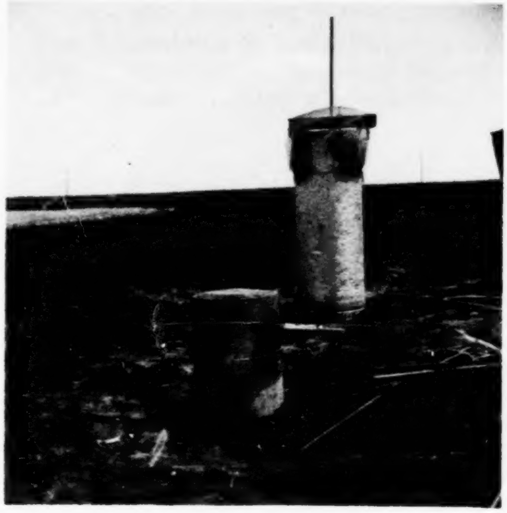


Figure 15. Evaporation Tanks Installed Adjacent To Infiltration Test Site.

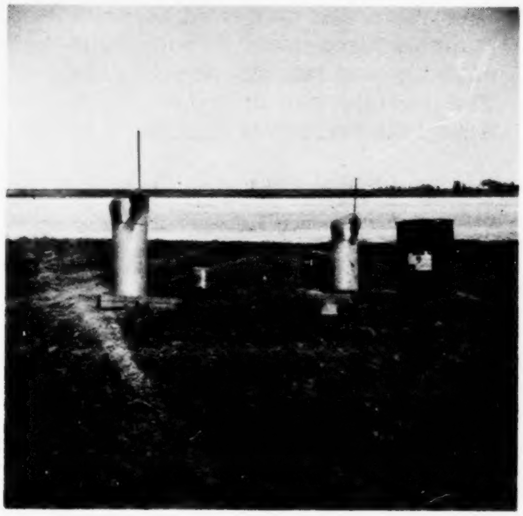


Figure 16. Infiltration Test Equipment In Operation At A Test Site.

Table 4. Infiltration Rates and Cumulative Amounts at Various Elevations of Lake No. VI (Holland)

Elevation	Accumulated Infiltration (feet)	Avg. Infiltration in Interval from 10 to 100 hours (feet per hour)
45.0	0.0752	0.00075
*46.0	0.271	0.001
47.0	6.05	0.06
48.0	42.8	0.438
49.0	46.5	0.455
Bottom of Pit	2.32	0.02

*The test at Elevation 46.0 was for a 90-hour duration. All the other tests were for 100 hour durations.

Several characteristics were observed to be common to the infiltration rates at all elevations. The initial infiltration rate always decreased rapidly to a point and then increased slightly before leveling off to a fairly constant value. The infiltration rates usually became fairly constant after 10 hours of testing, with the exceptions of elevations 48.0 and 49.0. In the more permeable locations (elevations 47.0 through 49.0) an increase in the infiltration rate was observed consistently at times of about 30 and 75 hours after testing had begun.

Soils

At each location in which an infiltration test was made, soil samples were taken every 6 inches through a depth of 24 inches. At elevations 48.0 and 49.0, the soil samples were taken through 30 inches and 36 inches respectively. A mechanical soil analysis was run on each soil sample and a particle size distribution curve prepared. The particle size distributions were obtained in accordance with the procedures of the American Society of Testing Materials.

The two soil properties which were obtained from these studies are the percent clay, (Pc), and the mean particle size, (M). The percent clay is the percentage of soil particles by weight that are equal to or smaller than 0.002 millimeters. The mean particle size is the size of soil particles of which there are 50 percent finer by weight. Both values are readily taken from the particle size distribution curves.

Table 5 shows the percent clay, Pc, in the top two feet of the soil profile at the various elevations. Table 6 shows the mean particle size, M, in the top two feet of the soil profile at the various elevations. Figure 17 shows a profile of the Holland Lake bed. This profile shows how the percent clay varies from the bottom of the lake to higher elevations. Also, as the percent clay decreases there is a noticeable increase in infiltration.

Infiltration versus Soil Properties

Linear regression analyses were made comparing effects of both percent clay and mean particle size on the infiltration rate. Due to the fact that in most instances the

Table 5. Percent Clay in First Two Feet of Soil Profile

Elevation Depth	Bottom of Excavation (I=0. 0208)	45. 0 (I=0. 00075)	46. 0 (I=0. 001)	47. 0 (I=0. 060)	48. 0 (I=0. 438)	49. 0 (I=0. 455)
0 - 6"	46. 25*	49. 0	47. 0	28. 0	19. 5	21. 0
6 - 12"	37. 75	56. 0*	53. 5*	28. 5*	23. 0	22. 0
12 - 18"	22. 0	50. 25	29. 5	26. 5	28. 5	22. 0
18 - 24"	33. 0	50. 0	23. 75	26. 0	31. 5*	26. 0*

*Least permeable clay layer

Table 6. Mean Particle Size, M, in First Two Feet of Soil Profile

Elevation Depth	Bottom of Excavation (I=0. 0208)	45. 0 (I=0. 00075)	46. 0 (I=0. 001)	47. 0 (I=0. 060)	48. 0 (I=0. 438)	49. 0 (I=0. 455)
0 - 6"	0. 0042*	0. 00255	0. 00295*	0. 0385*	0. 0915	0. 0630*
6 - 12"	0. 0435	0. 0010*	0. 0060	0. 0710	0. 0740	0. 0880
12 - 18"	0. 0970	0. 0019	0. 0540	0. 0770	0. 0550	0. 0790
18 - 24"	0. 0660	0. 00195	0. 0920	0. 0730	0. 0140*	0. 0660

*Least permeable layer based on mean particle size.

infiltration rate had become constant after 10 hours of testing, an average infiltration rate, "I", obtained after this time was used in these analyses (see Column 3, Table 4).

The regression analyses indicated that "I" was significantly related to Pc in the first 12 inches of soil, and also in the least permeable clay layer. These results are shown in Table 7. The relationships between "I" and Pc were found to be semi-logarithmic in all instances with the exception of the 18-24 inch layer which was a logarithmic function.

The regression analyses indicated that the mean particle size in the top 12 inches of soil was also a significant factor in explaining the infiltration rate. The 6 to 12 inch layer provided the highest correlation coefficient and was only slightly less than that obtained with the percent clay. These results are shown in Table 8.

RELATIONSHIP BETWEEN WATER LEVEL ELEVATION AND LAKE LEVEL DECLINE

Infiltration studies and soil analysis work at Lake No. VI (Holland) indicated that the farther from the center of the lake, and consequently the higher the elevation, the smaller the percent of clay in the soil of the lake becomes along with an associated higher infiltration rate. Therefore, it can be reasoned that, when water is in the lake, there is water percolating through the impermeable center as well as the more permeable fringe areas (see Figure 17). Because of this, the average lake level decline should increase as the lake water elevation increases.

Some analysis work pertaining to this hypothesis was done for Lake No.II (Knowles). Water level records at Lake No. II (Knowles) were reviewed, and a 3 day average water level decline obtained at all one-half foot increaments of elevation above the lake bottom. For instance, the water level records were studied and those periods when the water level was around elevation 49. 0 feet were noted; an average daily water level decline was obtained for a 3 day period at this elevation. Similarly, the average decline was obtained at 49. 5 feet, 50. 0 feet, 50. 5 feet, etc. up to an elevation 4 feet above the lake bed bottom.

A linear regression analysis was run on these data, and a correlation coefficient of 0. 86 obtained. The regression curve and the equation of the curve are shown in Figure 18. This shows the lake level decline to be only about 0. 03 feet per day when the water level is 0. 5 foot above the lake bottom. by contrast, when the water level is 4 feet above the lake bottom, the lake-level decline is about 0.07 feet per day. This shows, that in this lake, the daily lake level decline is more than doubled when the water level in the lake is at the higher level.

Evaporation and Percolation

Evaporation data are being collected by the Lubbock Agricultural Experiment Station utilizing a Young Screen Pan. These data are available for use by the project staff. During the past year this information was used to analyze the evaporation losses at Lake No. II (Knowles).

When taking pan evaporation data and projecting it to lake evaporation, it is

Table 7. Results of Linear Regression Analyses of Average Infiltration Rate, I, Versus Percent Clay, P_c.

Sample Depth	Regression Equation	Standard Deviation From Regression, Sy. x	t Value	Significance Level	Correlation Coefficient, r**
0 - 6"	$I=18.9(10)^{-0.08255 P_c}$	0.5176	4.920	0.01	0.9265
6 - 12"	$I=23.45(10)^{-0.08133 P_c}$	0.1622	16.838	0.001	0.9931
12 - 18"	$I=5.076(10)^{-0.07822 P_c}$	1.017	1.793	0.20	0.6625
18 - 24"	$I=20.99.0\ P_c^{-3.997}$	1.270	0.8255	0.50	0.3814
Least Permeable Layer	$I=76.53(10)^{-0.08702 P_c}$	0.4793	5.3747	0.01	0.9373

* Significance level indicates the probability of obtaining the corresponding t value this large or larger by chance above.

**Large values indicate good correlation.

Table 8. Results of Linear Regression Analyses of Average Infiltration Rate, I, Versus Mean Particle Size, M.

Sample Depth	Regression Equation	Standard Deviation From Regression, Sy. x	t Value	Significance Level	Correlation Coefficient, r**
0 - 6"	$I=29.22\ M^{1.6607}$	0.3528	7.531	0.005	0.9666
6 - 12"	$I=0.000659(10)^{32.667M}$	0.2748	9.801	0.001	0.9799
12 - 18"	$I=0.00116(10)^{21.667M}$	1.118	1.431	0.40	0.5821
18 - 24"	$I=0.0211(10)^{0.3683M}$	1.374	0.02165	Not signif. at any level	0.0108
Least Permeable	$I=33.38M^{1.5273}$	0.6834	3.491	0.05	0.8683

*Significance level indicates the probability of obtaining the corresponding t value this large or larger by chance above.

**Large values indicate good correlation.

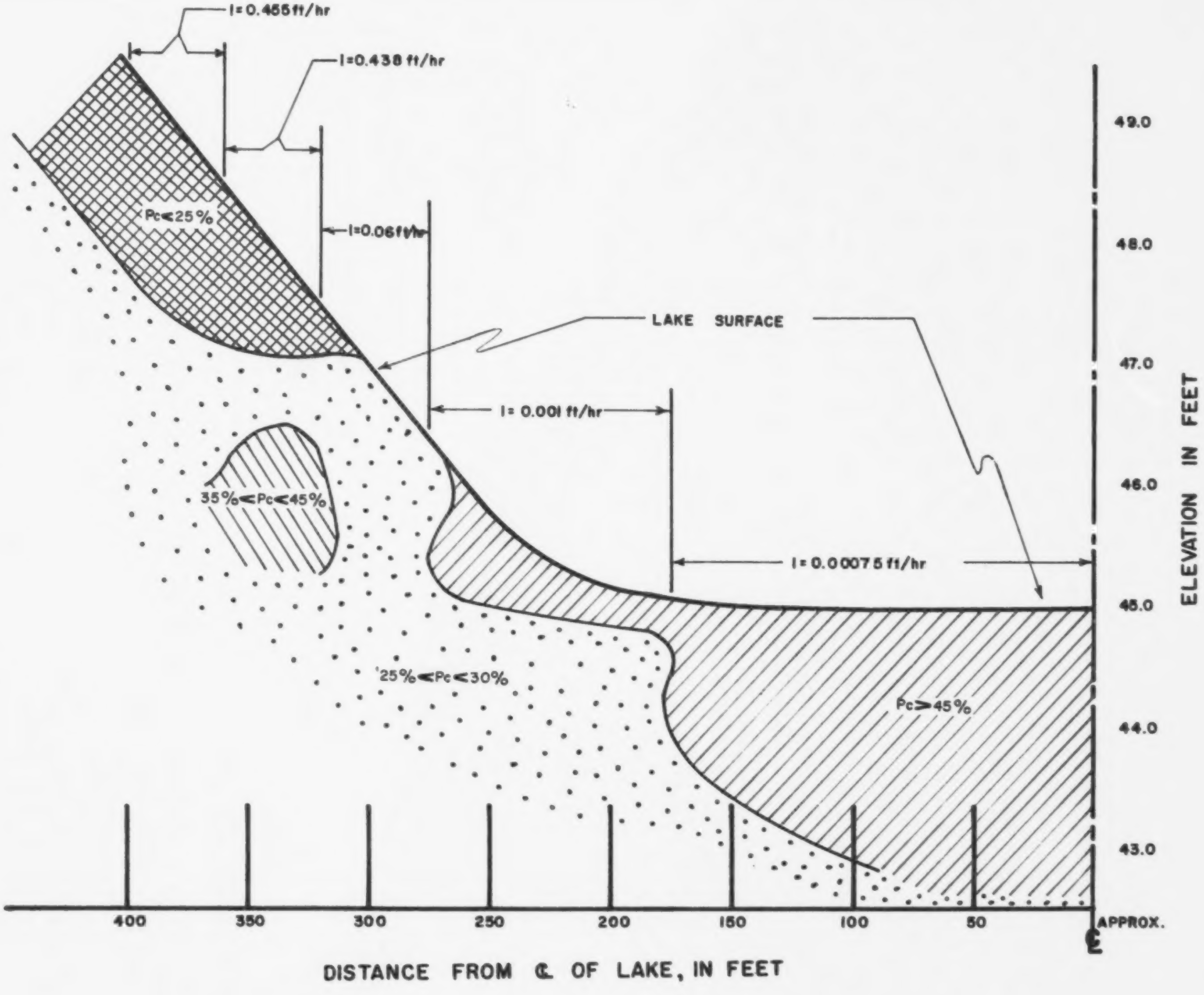


Figure 17. Lake Bed Profile of Lake No. VI (Holland).

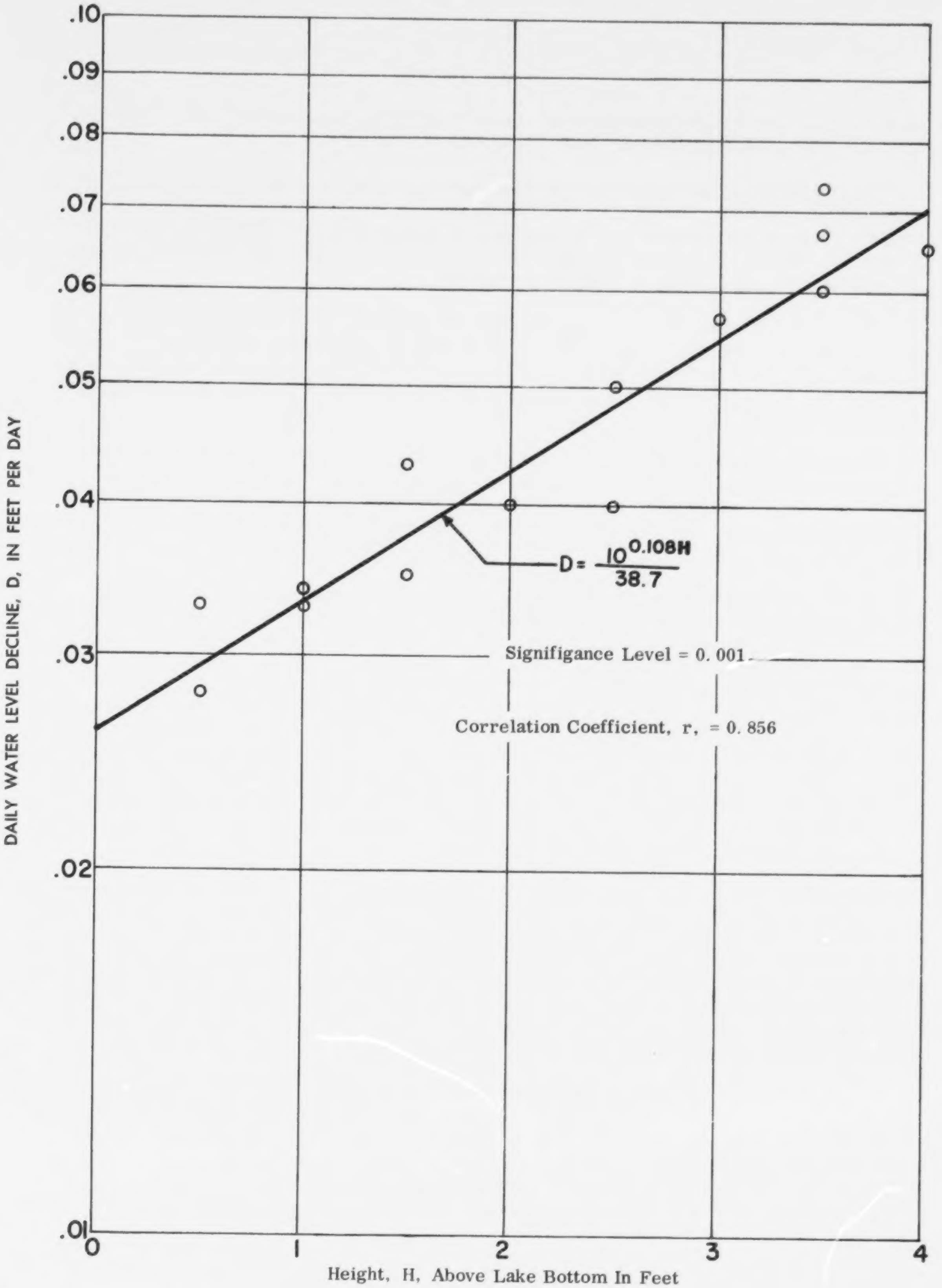


Figure 18. Relationship of the Average Daily Water Level Decline to the Elevation of the Lake Water Surface at Lake No. II (Knowles).

necessary to correct the actual pan readings by applying a pan coefficient to the data. The commonly used coefficient for a Young Screen Pan is 0.97.

The cumulative lake level decline was determined at Lake No. II (Knowles) for the years 1962 and 1963. Daily lake level declines were corrected for rainfall and runoff on days where such occurred. The cumulative decline was then plotted as shown in Figures 19 and 20. Cumulative evaporation curves, corrected by the pan coefficient, are also shown graphically in Figures 19 and 20.

During the summer and fall of 1962 there was a total of 32.2 inches of lake decline at Lake No. II (Knowles). During the same period of time there was only 18.5 inches of evaporation loss from the lake. This means that 57.5% of the water which collected in Lake No. II (Knowles) during 1962 was lost by evaporation and 42.5% was lost by percolation.

During the summer and fall of 1963 there was a total of 87.2 inches of lake decline at Lake No. II (Knowles). During the same period of time, only 35.5 inches of evaporation was lost from the lake. This means that 40.7% of the water which collected in Lake No. II (Knowles) during 1963 was lost to evaporation and 59.3% was lost to percolation.

The difference between the two years can be explained easily by recalling the previous section of this report which showed lake level decline increasing with elevation. The summer and fall of 1962 were relatively dry and the depth of water in the lake was never over 1.5 feet deep. However, the summer and fall of 1963 were wet and the depth of water was 4 feet at one time and was around 2.5 to 3 feet deep a large portion of the summer. Since the daily lake level decline increases with elevation and since the average 1963 lake elevation was 1.5 to 2.0 feet higher than in 1962 it becomes apparent that the average daily water level decline would also be higher for 1963 than 1962. With the average daily evaporation rate remaining approximately the same for the two years, a larger percentage of water would have to be lost to percolation in 1963 than 1962.

These results indicate a fallacy in past playa lake studies in which percolation and evaporation losses were determined on the basis of one year studies. Either one of the two years just analyzed could give false information by themselves. For the evaporation and percolation data to be accurate, records will need to be kept for several years and an average percentage of percolation loss obtained. This is something that has never been adequately resolved for the High Plains of Texas. Based on past studies, a common figure used for evaporation loss from playa lakes in the Southern High Plains of Texas is 90%. At the present time, this figure appears to be entirely too high for Lubbock County in which this study is being conducted.

CONSERVATION OF WATER

One of the primary purposes of lake modification is to conserve water. Prior to modification, the water was spread over several acres of land and was lost to evaporation and percolation. The modifications have confined the water to a much smaller area. Therefore, since the area is smaller, the daily volume of water lost to evaporation and percolation should be reduced.

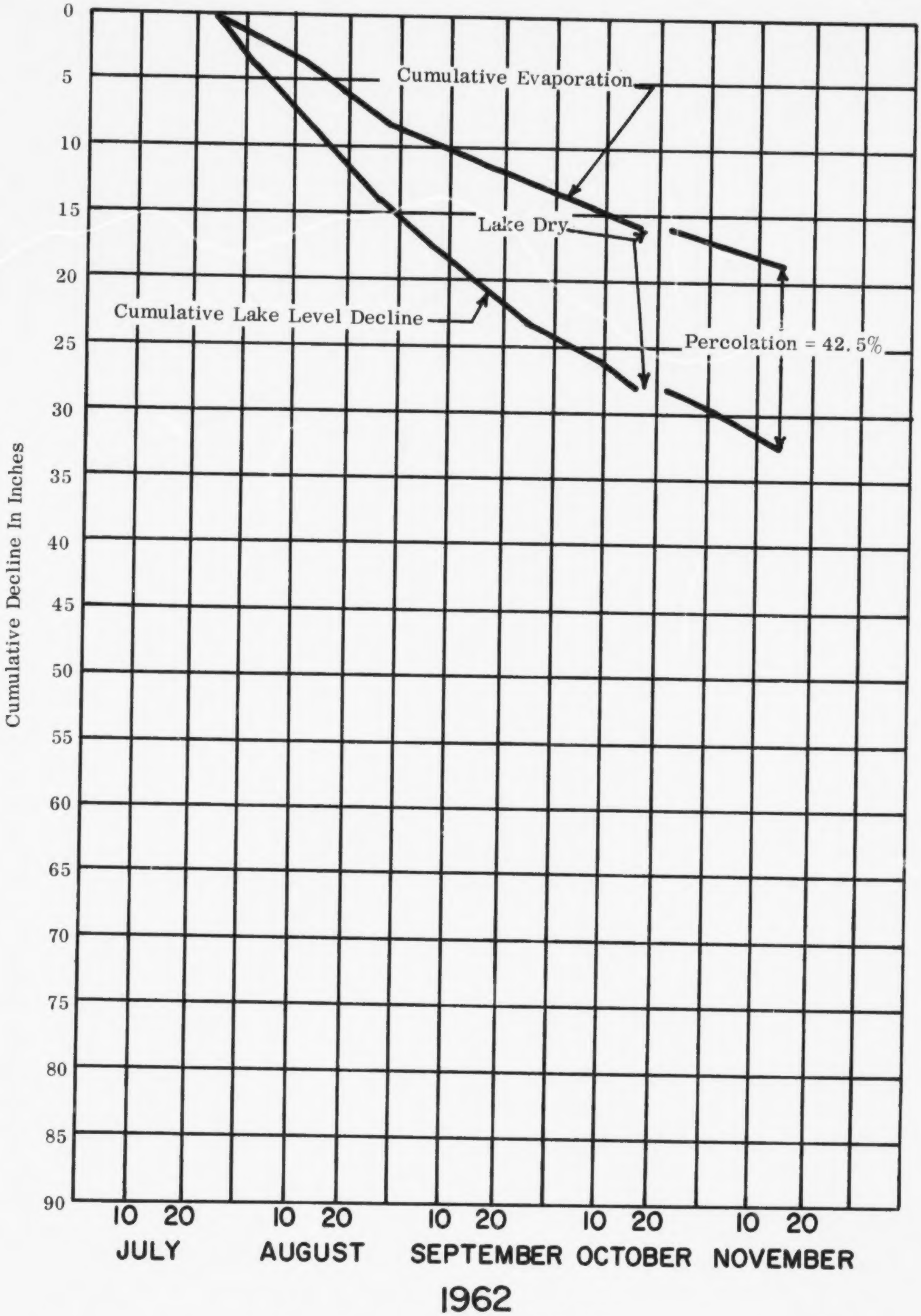


Figure 19. Cumulative Lake Level Decline and Cumulative Evaporation at Lake No. II (Knowles) During 1962.

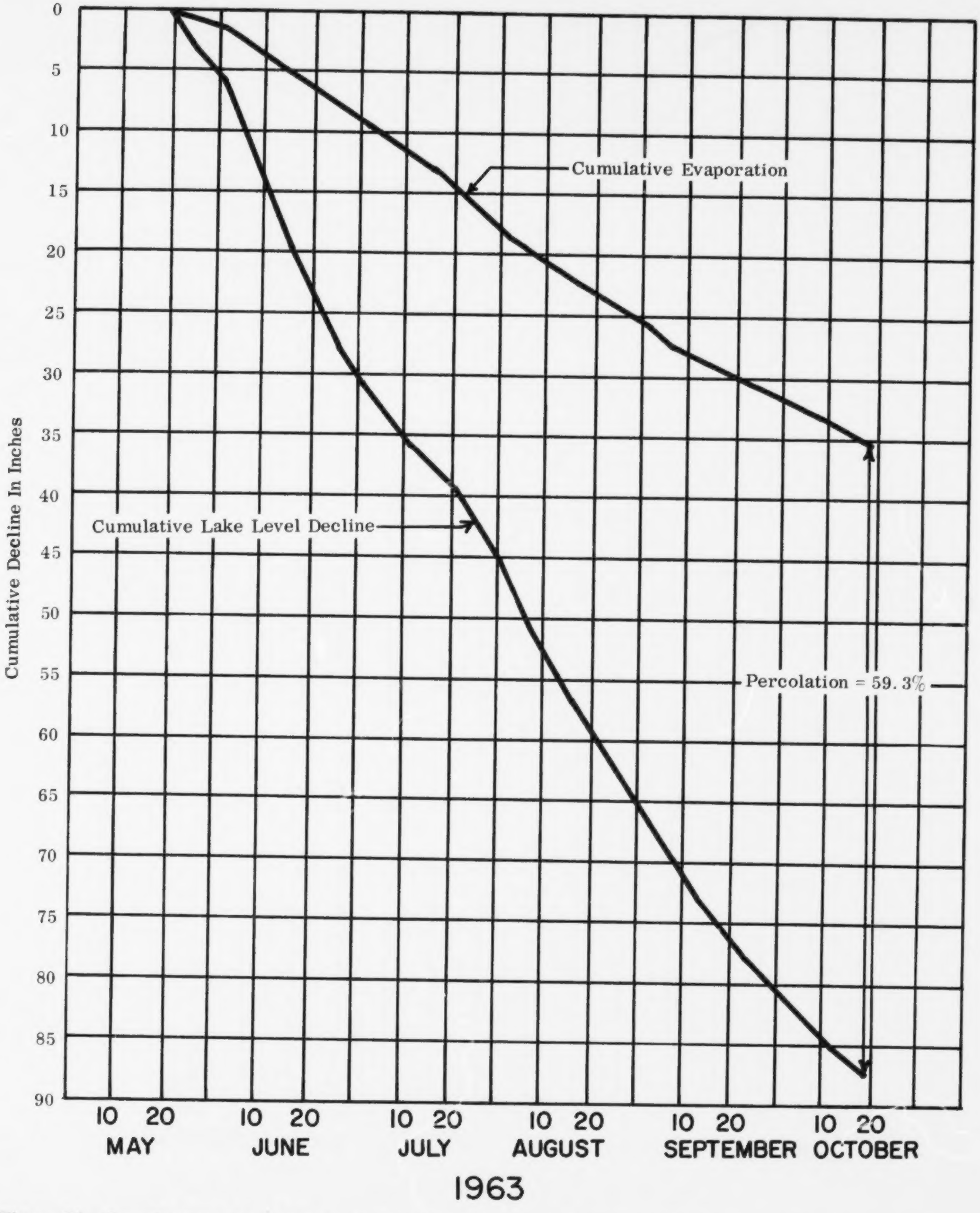


Figure 20. Cumulative Lake Level Decline and Cumulative Evaporation at Lake No. II (Knowles) During 1963.

This has proven to be a fact. Lake No. III (Hufstedler), Lake No. VI (Holland), and Lake No. V (Kitten) were usually dry by the middle of October every year prior to modification. Since modification, these lakes maintain water throughout the winter and well into the spring. Burgett lake was modified this past year and has not caught enough water to evaluate its water conservation potential. Table 9 shows the result of modifying lakes.

Table 9. Average Daily Volumes of Water Lost from Each Lake Before and After Modification

Lake	Avg. daily volume of water lost from lake during summer prior to modification(acre -feet per day)	Avg. daily volume of water lost from lake during summer after modification (acre-feet per day)
Lake No III (Hufstedler)	1.0	0.15
Lake No. V (Kitten)	1.6	0.07
Lake No. VI (Holland)	1.0	0.12

Table 9 shows that water conservation can be an important purpose of lake modification. Water in the modified lakes is available for use at least 10 times longer than in an unmodified lake. A detailed analysis of the water level records will reveal exact figures on the volume of water saved each year. These analyses are time consuming and will not be available until next year. However, there is little doubt that the modifications are providing water for use over a considerably longer period of time.

LAND RECLAMATION

Each of the lake modifications has reclaimed land which prior to modification was non-beneficial. Table 10 shows the acres of land reclaimed at each lake.

Table 10. Acres of land reclaimed by lake modification at each of the lakes

Lake	Land reclaimed in acres
Lake No. III (Hufstedler)	11.5
Lake No. IV (L. C. C.)	10.6
Lake No. V (Kitten)	13.0
Lake No.VI (Holland)	9.2
Lake No. VIII (Burgett)	8.1
Average for five lakes	10.5

Since the soil that was taken from the pits was spread evenly onto the adjoining lake bottoms, many persons figured that it would be next to impossible to grow crops on this reclaimed land. Soil samples were collected from the lake bottom and analyzed by the Soil Testing Laboratory at the Lubbock Experiment Station. These analyses show that the soils used for fill material were very low in organic matter, very low in nitrogen, very high in phosphorus, very high in potassium, very high in calcium and very low in salinity hazard.

Lake No. V (Kitten) was planted in a grain sorghum crop during the summer of 1964. Four acres of the lake bottom were watered one time. The remaining nine acres were dry land. Nitrogen was applied on five acres of the lake bottom at the rate of 70 pounds per acre. The remaining eight acres received no fertilizer. The crop received only about five inches of rainfall all year. Yet, when the grain was harvested, it made an astounding 3200 pounds per acre. Mr. Kitten said that this was a greater yield than some of his irrigated grain which was watered two times. The modification on Lake No. V (Kitten) is shown in Figure 21 and the grain sorghum crop grown on the reclaimed land is shown in Figure 22.

At Lake No. IV (L. C. C.), experiments were conducted to determine the changes in infiltration rate caused by various cropping patterns in one year's time. With its original slow permeability, and the packing effect of the heavy excavating equipment during modification, the disturbed soil in the fill area appeared to be in very poor condition for crop production. Preliminary observations on wheat drilled into the disturbed soil showed that, even when sufficient moisture was available, emergence was very slow and root development shallow. The soil was so firmly packed that an attempt to chisel with a Graham plow to a depth of six inches resulted in broken chisels.

An experimental area was protected by a diversion terrace and bench leveled for irrigation. Within this area cotton burrs were used as a source of dry organic matter, applying four rates of this organic source, and using two fertilizer levels to grow three test crops. These were forage sorghum,Cado switchgrass, and volunteer plant growth on "layout" land. All areas were irrigated and fertilized on a similar schedule; no tillage was practiced on the layout area. Table 11 presents the results from these plots.

Table 11. Yield Data From Experimental Plots At Lake No. IV(L. C. C.) (1)

Treatment	Layout Land (avg. of 3 reps)	Grass (avg. of 3 reps)	Forage Sorghum (avg. of 3 reps)	Average
1	15	10	37	21
2	12	10	32	18
3	16	9	39	21
4	23	15	49	29
Average	16	12	39	

(1) Note: Yields above indicate the pounds of clip obtained from 1/1000 acre. There were 3 replicates of each treatment. The yield from the layout land consists of weeds, wild grass, etc.

Preliminary checks indicated increased infiltration rates varying from 1/3 inch per hour on the check plot (no burrs, no fertilizer, no crop) to one inch per hour on a treatment of 20 tons of burrs, high fertility and with a crop. This preliminary check indicated an average infiltration rate increase for all treatments on forage sorghum to be above 1/2 inch per hour (for a one hour period). These figures are preliminary since much of the field work and laboratory analysis will not be completed until the winter of 1964-65.

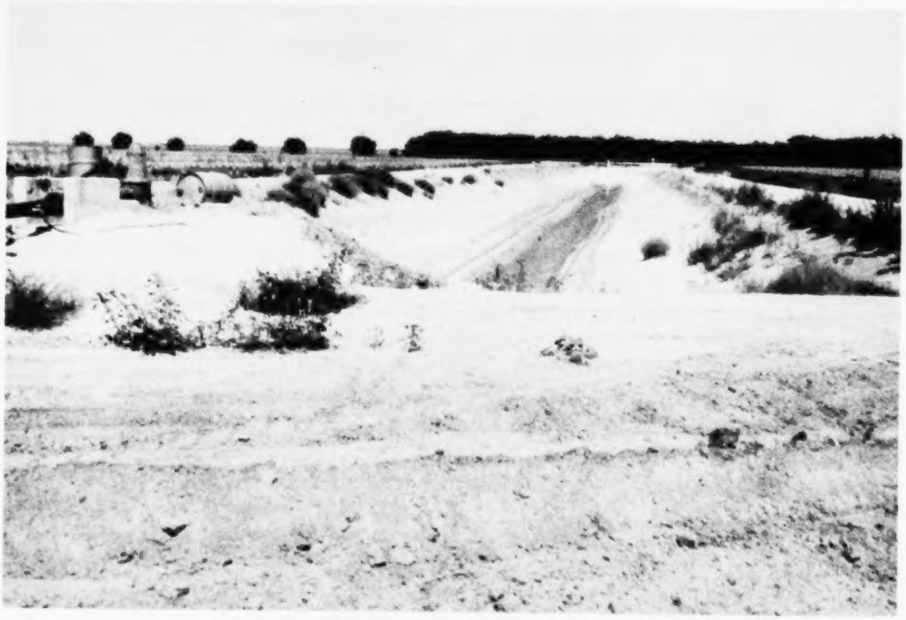


Figure 21. Modification at Lake No. V (Kitten) Showing Crop Growing Along the Edges of the Pit.

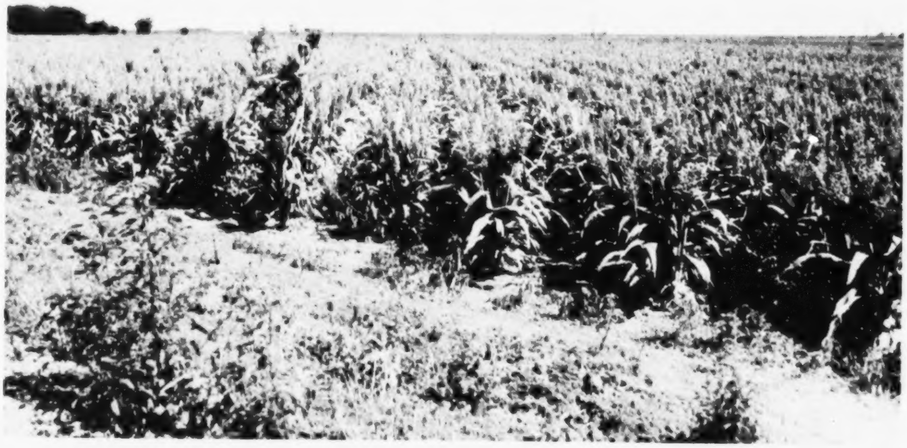


Figure 22. Grain Sorgham Crop Growing on Reclaimed Lake Bed at Lake No. V (Kitten). Grain Yielded an Average of 3200 Pounds per Acre.

BENEFIT - COST ANALYSIS
OF
MULTIPURPOSE PLAYA LAKE MODIFICATION

Research has been directed toward the development and assembly of data needed to answer questions pertaining to feasibility of modifying, for multipurpose uses, the numerous playa sinks of the Texas High Plains. Several potential sources of benefits from lake modification have been identified--reduced illness through mosquito control, increased number of acres of farmland through concentration of water into deeper basins having less surface area exposed to evaporation, increased water, and increased potential for recreation centered around picnicking, hunting and fishing. Even though some benefits may be forthcoming from part or all of the above sources, it is not clear that total benefits will exceed total cost of multipurpose modification. Some of the potential sources of benefit will compete with other sources, thus reducing the potential benefits per dollar cost of including a particular purpose. For example, the use of lake water for irrigation competes with the use of water for recreation, thereby reducing the amount of benefits which can be realized from use of the facility for recreation. Additional investments in development of features required for recreational uses of modified playa lakes would, therefore, return lower benefits than if lake water were not used for irrigation.

In developing criteria whereby decisions about investments in multipurpose modifications of playa lakes can be made, proper account must be taken of all the potential sources of benefits, competition among sources of benefits, and costs of including facilities for each of the purposes of the overall modification project. Project WP 29 has progressed in the development of the technical relationships between playa lake development inputs and outputs. The technical data must be transformed into dollar values through application of the economic variables--prices of products and inputs, and interest rates--before decisions and whether or not to engage in lake modification projects can be made.

The simplest way to decide whether or not to incur investments of the nature required for multipurpose playa lake modification is to conduct a benefit-cost analysis of modification projects. Multipurpose modification projects of this nature require current outlays for project construction, from which a stream of future benefits are presumably obtained. However, benefits to be received in the future are worth less today than current benefits of the same amount, because of uncertainty associated with the future and because capital investments in other pursuits are productive with time. Therefore, the stream of benefits must be discounted to present values if correct decisions are to be made concerning project implementation.

Techniques for evaluating benefits and costs of multipurpose playa lake modification projects are set forth below. It is anticipated that the date required for the proposed benefit-cost analysis will be supplied in part by Project WP 29 and in part by secondary sources including farmers, physicians, merchants and others in the local community.

Benefits

The expected benefits from multipurpose modification can be expressed as follows:

$$(1) \qquad B = \int_0^n b_1 e^{-rt}\,dt + \int_0^m b_2 e^{-rt}\,dt + \int_0^p b_3 e^{-rt}\,dt + \int_0^s b_4 e^{-rt}\,dt\,.$$

Where B is the present value of future benefits from all sources of the multipurpose project. b_1 is annual benefits from health, b_2 is annual benefits from increased water. b_3 is annual benefits from reclaimed land. b_4 is annual benefits from added recreation (includes wildlife), and r is the interest rate. Health benefits are expected to last for n years, water benefits are expected to last for m years, land benefits are expected to last for p years and recreation benefits are expected to last for s years. The lives of each of the parts of the projects are not necessarily equal, however, they may be: i. e. n=m=p=s years. Time is referred to by t and the integral over the life expectancy of each part is the present value of income expected from that portion of the project. The computing formula for evaluating benefits is as follows if the annual benefits, b_1, b_2, b_3, b_4 are constant dollar values for each year of project usefulness. In case

$$(2) \qquad B = \frac{b_1\left[1 - e^{-rn}\right]}{r} + \frac{b_2\left[1 - e^{-rm}\right]}{r} + \frac{b_3\left[1 - e^{-rp}\right]}{r} + \frac{b_4\left[1 - e^{-rs}\right]}{r}$$

annual benefits are also a function of time; i.e. either increase or decrease as the project progresses with time, then the integrals of equation (1) will be of the form $\int_A b(t)\, e^{-rt}\, dt$; in which case evaluation becomes slightly more difficult because of the complexity of the function. In either case the resulting estimate, B, is an estimate of the present value of the project even though production will be distributed throughout future years.

Costs

Multipurpose playa lake modification requires initial capital outlays for project construction, local area stabilization, and special equipment for some of the purposes of installation, such as recreational facilities. In addition there likely will be some periodic maintenance either annually or less often. The costs of multipurpose modification can be expressed as follows:

$$(3) \qquad C = I + \int_A c\, e^{-rt}\, dt$$

where C is the present value of project cost, I is cost of modification and includes earth moving, land shaping, stabilizing the site under construction, facilities for recreation, and any other specialized equipment used by one or more of the purposes for which maintenance cost will be incurred in the future, and the integral over the time span A evaluates that future cost in terms of the present, at interest rate r. The time of occurrence of maintenance must be used instead of the time span of zero to some future year and is unspecified in equation (3). The time of these maintenance costs are not yet known. Future costs are discounted at the same rate of interest as future revenues are discounted. Investment or installation costs are not discounted because these outlays occur at the beginning of the project and in fact are present values.

Net Benefits

The difference between present value of total benefits and total costs is the present value of net benefits to the project. Net benefits can be expressed as follows:

(4) $N = B - C$

where N is present value of net benefits, B is present value of total benefits and C is present value of total costs. If net benefits are greater than or equal to zero then the project would presumably be undertaken. When net benefits are exactly zero the project yields a rate of return equal to r, the rate of interest at which future benefits and costs have been discounted. If net benefits are greater than zero then the project would return a yield greater than the discount rate and if net benefits are negative the project would actually yield a rate of return that is less than the rate at which future benefits and costs have been discounted.

Few investors are expected to undertake projects which promise negative net benefits. In fact, when there are alternative projects available for consideration, investors who are profit-motivated can be expected to rank projects according to net benefits, when interest rates and time horizons are equal, beginning with those which show highest dollar values. Investments are ordinarily made in projects which show highest net benefits first and then if more capital is available investments are made in projects with second highest net benefits and so on, down the list until either capital funds for investment are exhausted or net benefits for the remaining investment opportunities are negative. Of course, when investment capital is unlimited, investors can be expected to undertake projects which yield zero returns; i. e. future total benefits and total costs are discounted at zero interest rate and net benefits also equal zero. The case of virtually unlimited capital has seldom if ever been observed in practice; therefore, for parctical pruposes this is a trivial case.

The West Texas community can safely assume that investment capital is limited, that there are many opportunities for investments, and that other alternatives are actively competing with multipurpose playa lake modification projects for this limited capital. Therefore, estimation of net benefits to playa modification projects will make available information concerning one more investment opportunity. Net benefits will be estimated under a variety of economic conditions (various prices for products from the projects, and various interest rates) so that all types and classes of investors will find useful investment information--not all investors hold the same views or have the same criteria for making investments. The water development purpose, the potential health benefits and the potential recreational uses of modified playa lakes are all important attributes to the West Texas area. The shortage of these facilities in the area indicates that actual benefits may be high and therefore playa lake modification will be an attractive investment alternative.

Private investors usually expect to receive high rates of return on investments; i. e., r must be large. The present value of future income is low when interest rates are high. On the other hand the community or society places higher value upon future income; and therefore has somewhat lower interest rates than most private investors do. The present value of future income increases as the interest rate, r, decreases. Estimates of present values of investment type projects, at various levels of interest rates provides the basis for resolving conflicts between the viewpoints of private investors and those of the public. This is particularly important with respect to multipurpose playa lake modification, because for health reasons it appears that the general public is very much interested in modifying playas. However, if rate of return from modification projects is too low, private investors may not invest in multipurpose playa lake modification projects. Estimates of the kind outlined in this report will provide both the private and the public sectors of the economy with information pertaining to the productivity of modification projects. In case benefits are not sufficiently high to attract the required investment funds from private sources, the public sector will have a basis for deciding whether or not to enter into playa modification projects or to loan funds, at lower interest rates, for playa modification.

COMPETITION OF PURPOSES WITHIN MULTIPURPOSE MODIFICATION

The equations of the above discussion state the benefits and costs as if there were no competition between parts of the multipurpose projects. This is not the case, however, because, for example, the use of water for recreation or irrigation are direct competitors. With limited water there cannot be unlimited irrigation or recreation. Therefore, the substitution rates of one part of the project for other parts must be determined. If all impounded water is used for irrigation there will likely be no benefits from recreation and little, if any, mosquito production; a condition which means near, if not maximum, health benefits.

The substitution relationships of the various parts of the multipurpose projects must te expressed in exact form so that benefits can be accurately evaluated. At this point in the research under Project WP 29 the competition of portions of the projects for other portions is not clear, because benefits of each part of multipurpose lakes have not been accurately estimated. The plan of work includes an analysis of the competition between the various purposes, as an integral part of the overall economic evaluation of multipurpose playa lake modification. At present, however, there is no data pertaining to some of the purposes; i. e., recreation, which are adequate for this purpose.

FUTURE WORK PLANS 1964-1965

Dipping of playa lakes for mosquito production will be continued on twelve lakes during the next year. Five of the lakes have been modified and three of the lakes have small pits for the mosquito minnow *Gambusia affinnis affinnis.* Statistical evaluation of dipping data collected the last three seasons are being analyzed and a statistically sound dipping procedure is being formulated.

Water chemistry studies will be continued throughout the next year on modified and unmodified playas. Since two of the project study lakes were stocked with large mouth bass, channel catfish, and bream sunfish in the summer of 1964, comparisons of plankton and water chemistry can be studied in stocked and unstocked modified playas.

Growth rates of the fish stocked in the two modified lakes will be recorded. Feeding studies on fish will be initiated at one lake in conjunction with feeding studies being done on catfish in small ponds at Texas Technological College.

Vegetation studies will consist of staking permanent plots on modified and unmodified playas. Revegetation on modified playas will be compared with that of undisturbed, unmodified playas.

In connection with vegetation studies, a collection of birds and mammals for museum specimens will be made from the playa and its watershed. Crop and stomach contents of animals collected will be examined to find out what portion of their food comes from playas. Wildlife counts will be contunued on all study lakes.

Bionomic studies of Culex quinquefasciatus will be extended; also, efforts to colonize Culiceta inornata and Culex tarsalis will be continued. In the spring, summer and fall, bionomic studies will be made in the field and laboratory.

Studies will be made this winter on build up of pesticide residue in the soil and water of playa lakes. This work will be implemented by the gas chromatograph recently purchased by this project.

Rain gauges, water level recorders and staff gauges will be maintained on a weekly schedule. During the coming year, additional time will be spent analyzing each lake for evaporation and percolation losses. Also, determinations will be made of the volume of water conserved by each of the modified lakes.

Continued studies of the effect of cropping patterns and tillage methods on the infiltration of lake soils will be made. Records of the crop yields on the reclaimed lake bottom land will be kept. Some preliminary investigations on the adaptability of the modified lakes for the use of flocculating chemicals to floc the suspended sediment from the lake water will be made. If clear water can be obtained, a "door" will be opened for artificial recharge operations.

This project has successfully obtained data pertaining to mosquito control and water supply development by modified playa lakes. This data must be supplemented by additional information in the following areas: (1) evaporation rates in West Texas, (2) demands for the types and kinds of recreation supplied by modified playas, (3) information about number of cases and costs of encephalitis in the area, (4) productivity of lake water in irrigated agriculture, (5) productivity of land to be developed by the modification, within the context of current government acreage control programs, and (6) costs of lake modifications. Some parts of this data is yet to be assembled. This will be done in part through interviews of farmers and the general public and in part through other means. County health records, published research of various local and state agencies, and current research will be drawn upon for the information needed to evaluate net benefits from playa lake modification.

At this stage of the project, the data are not sufficient to carry out a complete economic analysis. More information is required before meaningful relationships can be derived and useful estimates established. Extensive empirical economic analysis of multipurpose modification of playa lakes is scheduled to begin in 1965 under a closely cooperating project in the Department of Agricultural Economics at Texas Technological College.

APPENDICES

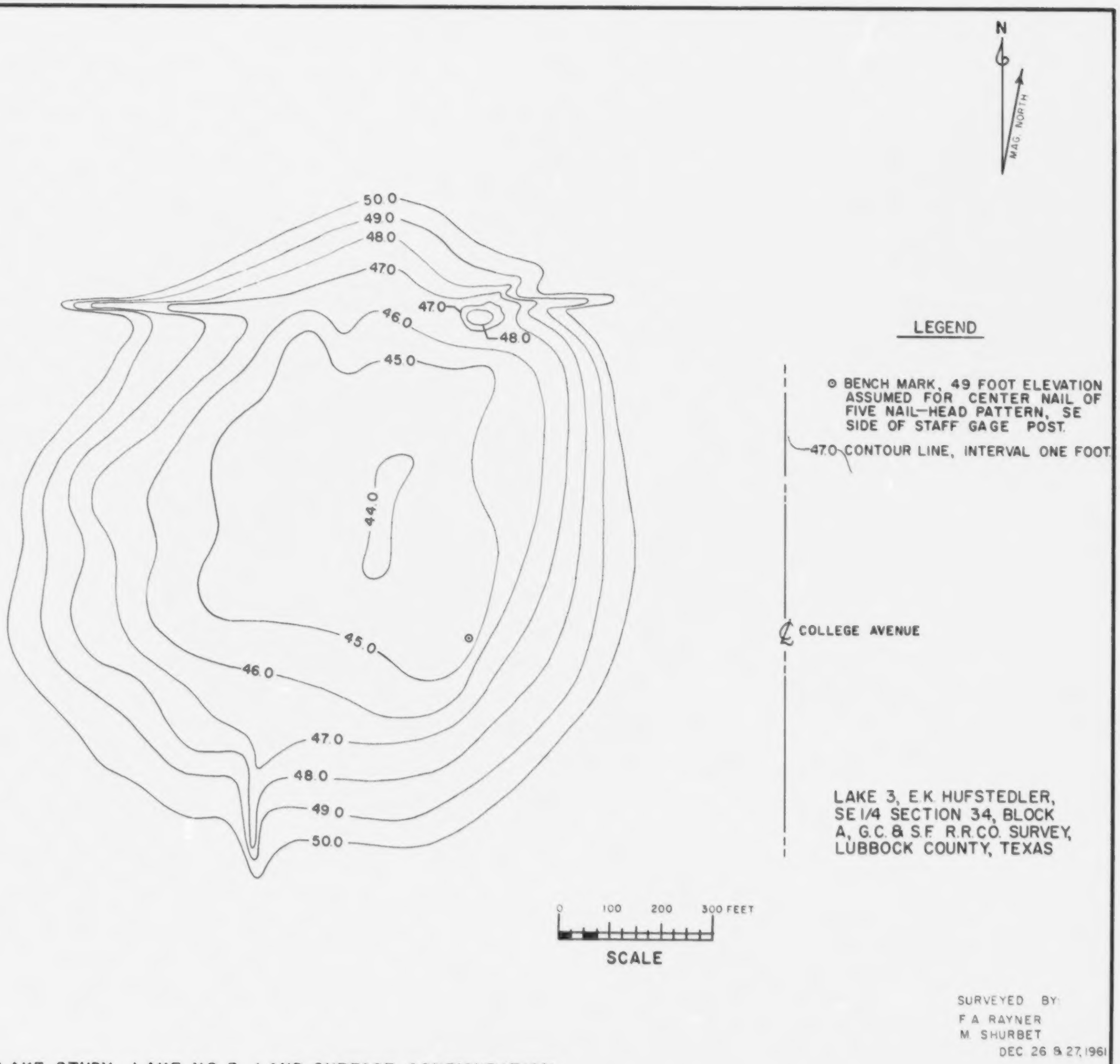
I. Maps of Lakes and Rating Curves

II. Daily Curves and Cumulative Curves on Each Lake

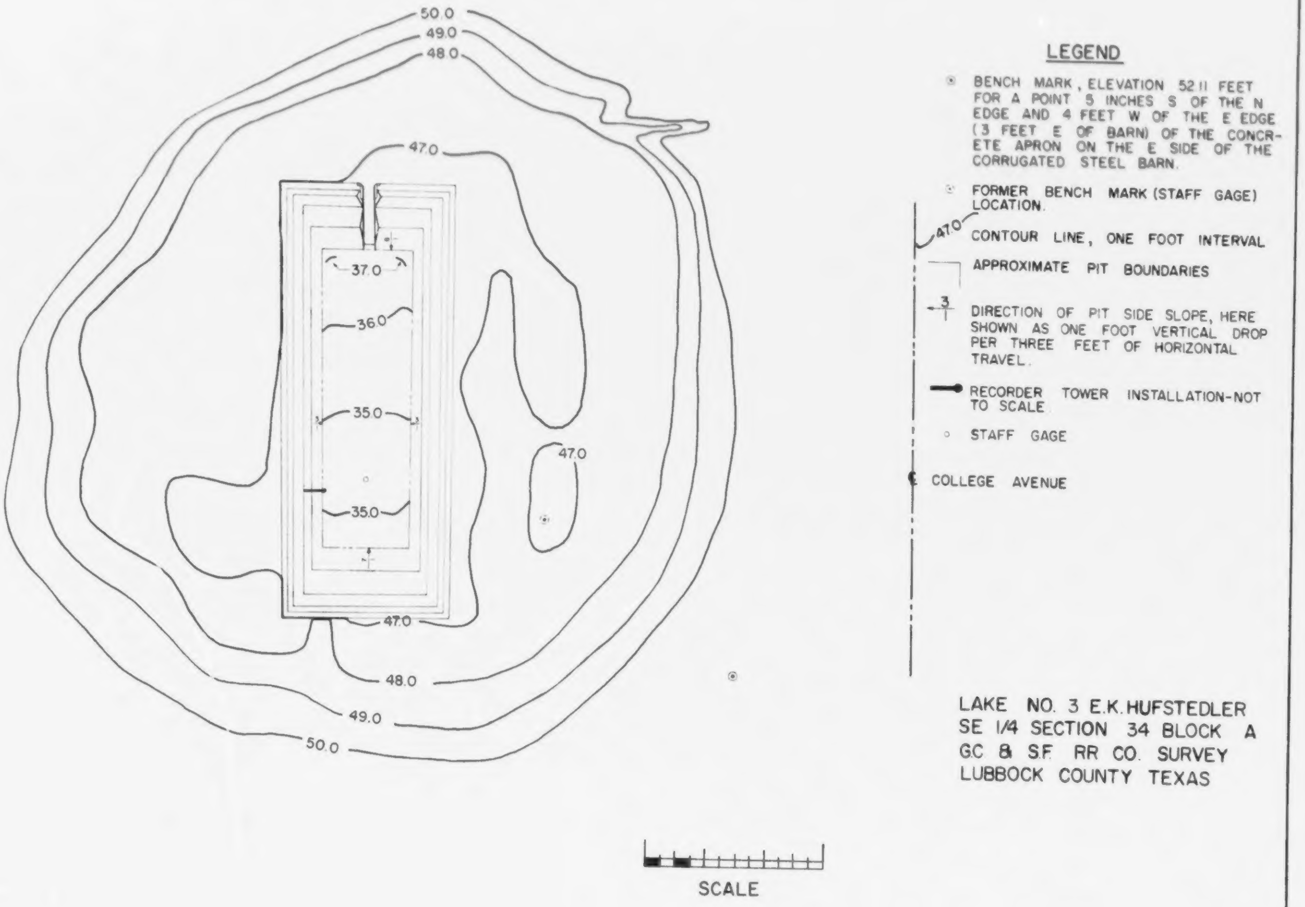
III. Mosquito Larvae Production Graphs and Mosquito Data Chart, Weekly Net Plankton and Vegetative Observations

APPENDIX I.

Maps of Lakes and Rating Curves


N
MAG. NORTH
50.0
49.0
48.0
47.0
47.0
48.0
46.0
45.0
44.0
45.0
46.0
47.0
48.0
49.0
50.0
LEGEND
⊙ BENCH MARK, 49 FOOT ELEVATION ASSUMED FOR CENTER NAIL OF FIVE NAIL-HEAD PATTERN, SE SIDE OF STAFF GAGE POST.
47.0 CONTOUR LINE, INTERVAL ONE FOOT
℄ COLLEGE AVENUE
LAKE 3, E.K. HUFSTEDLER, SE 1/4 SECTION 34, BLOCK A, G.C. & S.F. R.R.CO. SURVEY, LUBBOCK COUNTY, TEXAS
0 100 200 300 FEET
SCALE
SURVEYED BY:
F.A. RAYNER
M. SHURBET
DEC. 26 & 27, 1961

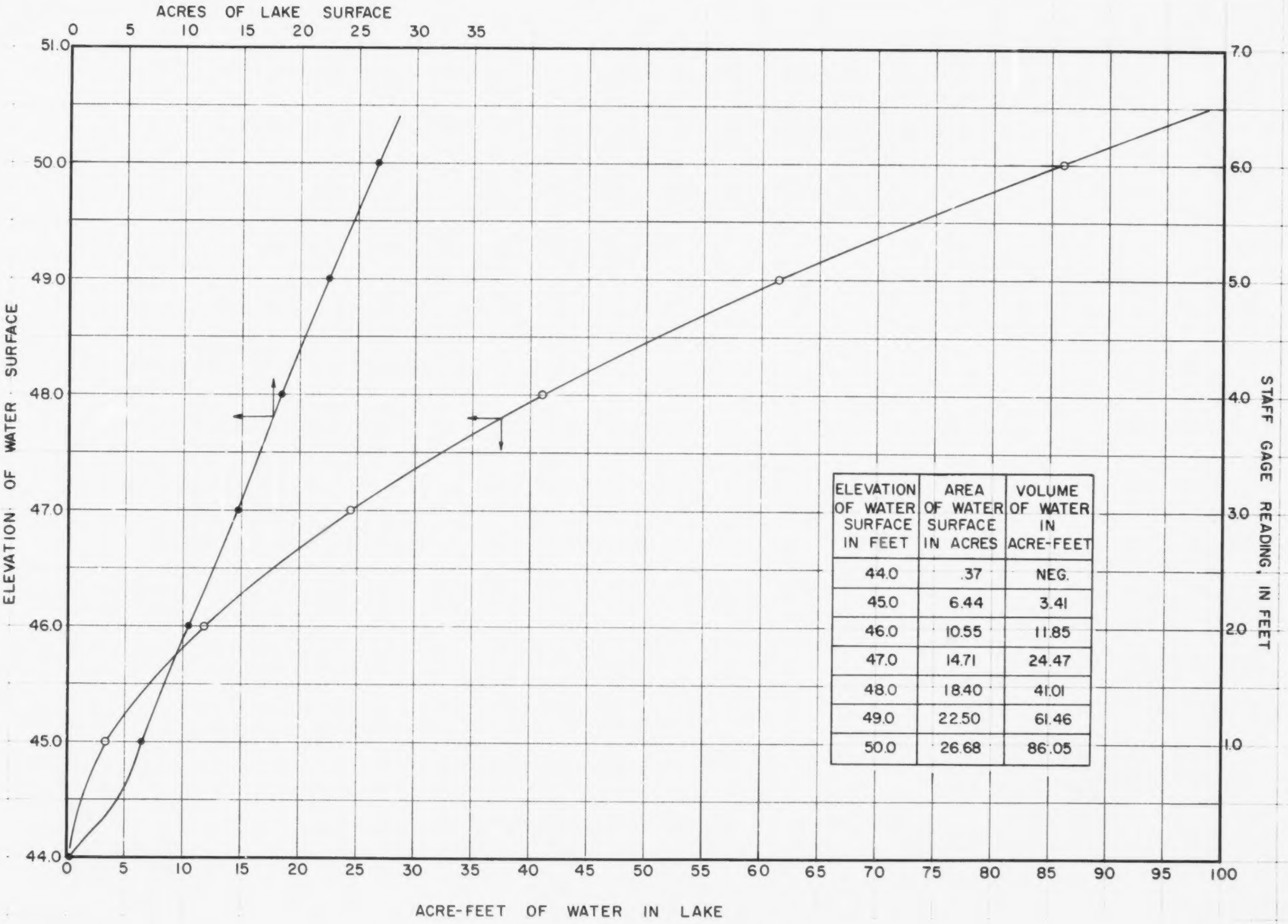
PLAYA LAKE STUDY, LAKE NO. 3, LAND SURFACE CONFIGURATION



50.0
49.0
48.0
47.0
37.0
36.0
35.0
35.0
47.0
47.0
48.0
49.0
50.0
LEGEND
BENCH MARK, ELEVATION 52.11 FEET FOR A POINT 5 INCHES S OF THE N EDGE AND 4 FEET W OF THE E EDGE (3 FEET E OF BARN) OF THE CONCRETE APRON ON THE E SIDE OF THE CORRUGATED STEEL BARN.
FORMER BENCH MARK (STAFF GAGE) LOCATION.
47.0
CONTOUR LINE, ONE FOOT INTERVAL
APPROXIMATE PIT BOUNDARIES
3
DIRECTION OF PIT SIDE SLOPE, HERE SHOWN AS ONE FOOT VERTICAL DROP PER THREE FEET OF HORIZONTAL TRAVEL.
RECORDER TOWER INSTALLATION-NOT TO SCALE
STAFF GAGE
COLLEGE AVENUE
LAKE NO. 3 E.K. HUFSTEDLER
SE 1/4 SECTION 34 BLOCK A
GC & SF RR CO. SURVEY
LUBBOCK COUNTY TEXAS
SCALE

PLAYA LAKE STUDY, LAKE NO. 3 LAND SURFACE CONFIGURATION

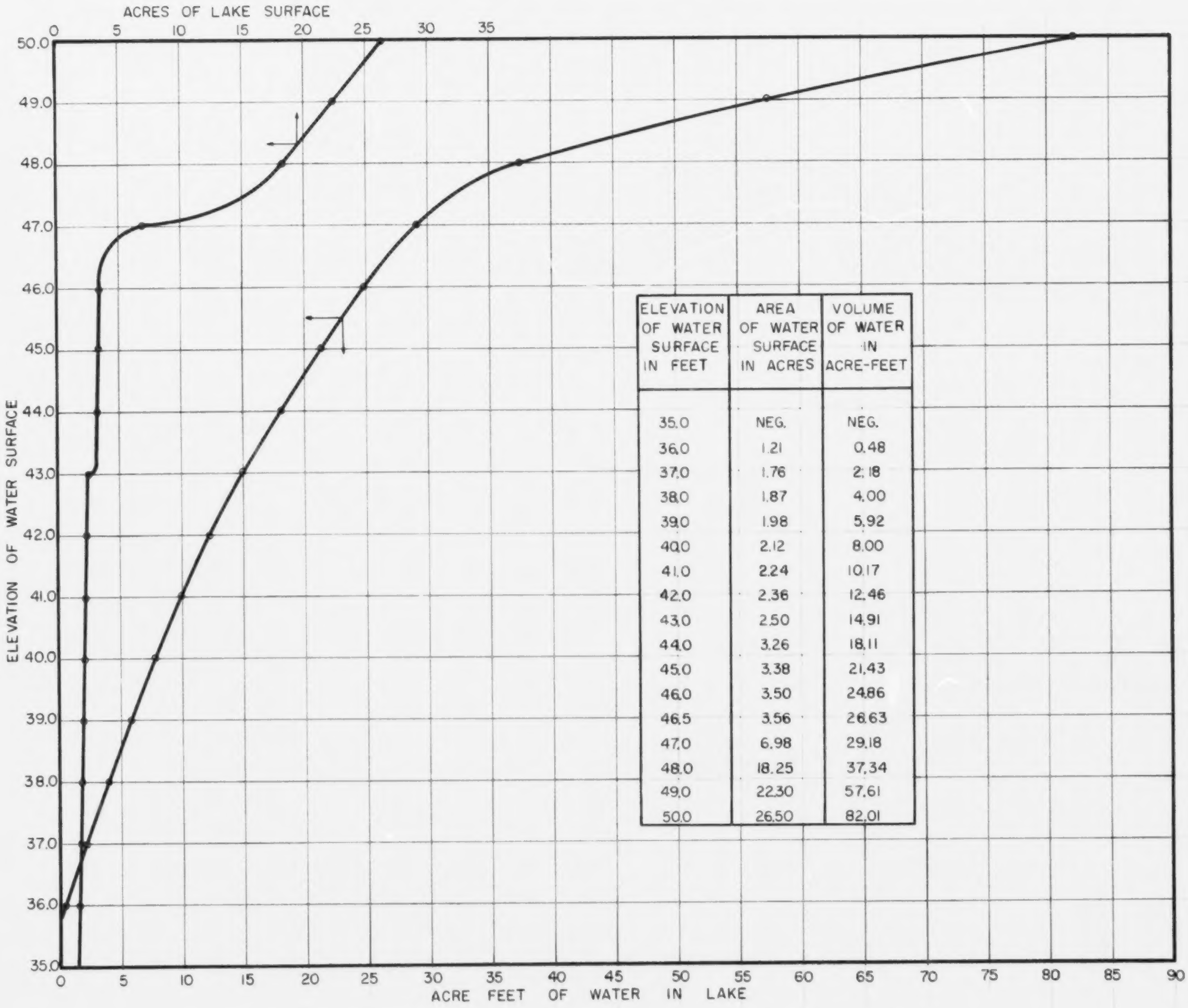
SURVEYED
JUNE 1964



ELEVATION OF WATER SURFACE IN FEET	AREA OF WATER SURFACE IN ACRES	VOLUME OF WATER IN ACRE-FEET
44.0	.37	NEG.
45.0	6.44	3.41
46.0	10.55	11.85
47.0	14.71	24.47
48.0	18.40	41.01
49.0	22.50	61.46
50.0	26.68	86.05

AREA-VOLUME-ELEVATION CURVES FOR LAKE NO. 3, LOCATED IN SE 1/4 OF SECTION 38, BLOCK A, G.C. & S.F. R.R. CO. SURVEY, LUBBOCK COUNTY, TEXAS.

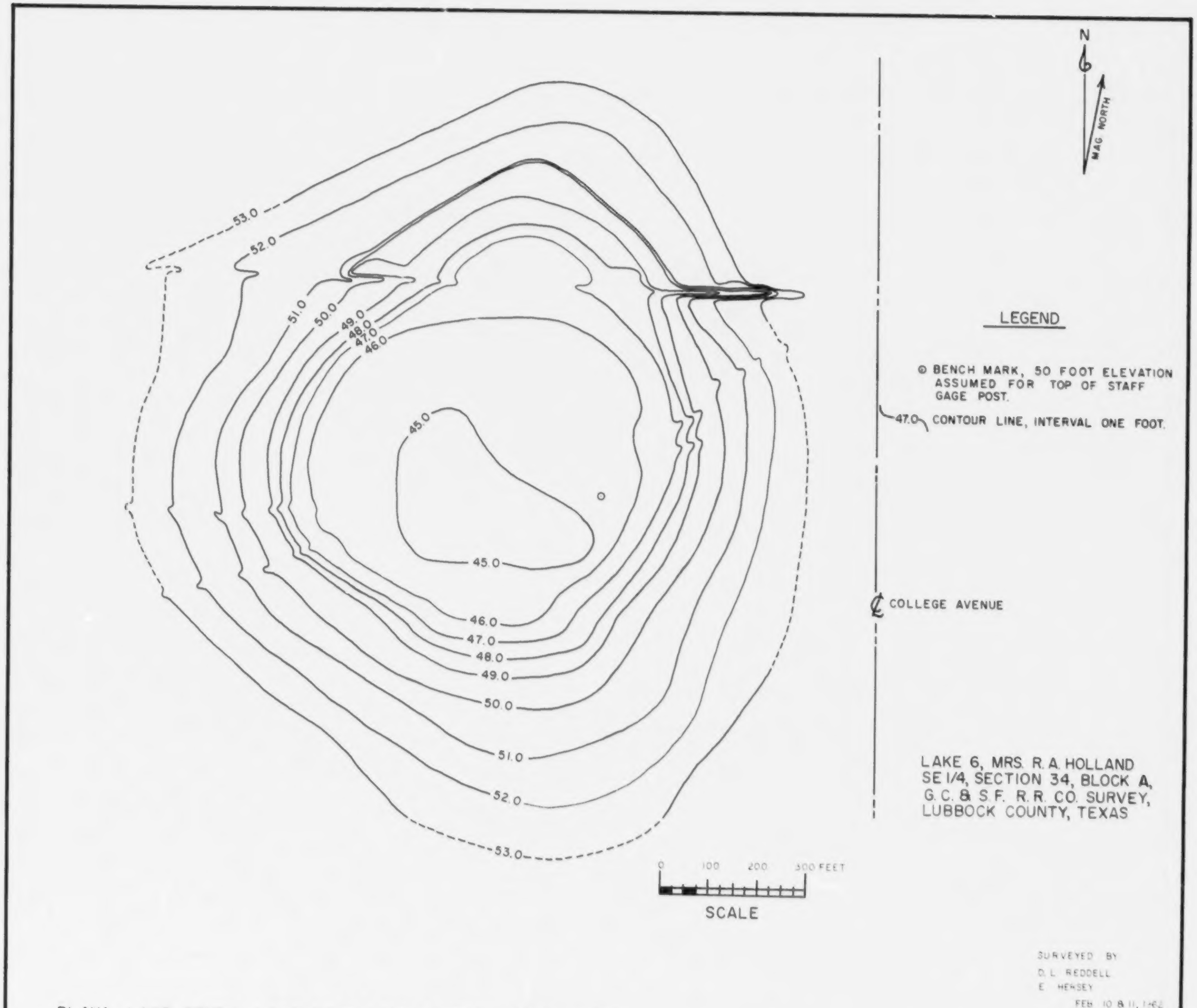
DRAWN BY: F.A. RAYNER
JAN. 1, 1962



ELEVATION OF WATER SURFACE IN FEET	AREA OF WATER SURFACE IN ACRES	VOLUME OF WATER IN ACRE-FEET
35.0	NEG.	NEG.
36.0	1.21	0.48
37.0	1.76	2.18
38.0	1.87	4.00
39.0	1.98	5.92
40.0	2.12	8.00
41.0	2.24	10.17
42.0	2.36	12.46
43.0	2.50	14.91
44.0	3.26	18.11
45.0	3.38	21.43
46.0	3.50	24.86
46.5	3.56	26.63
47.0	6.98	29.18
48.0	18.25	37.34
49.0	22.30	57.61
50.0	26.50	82.01

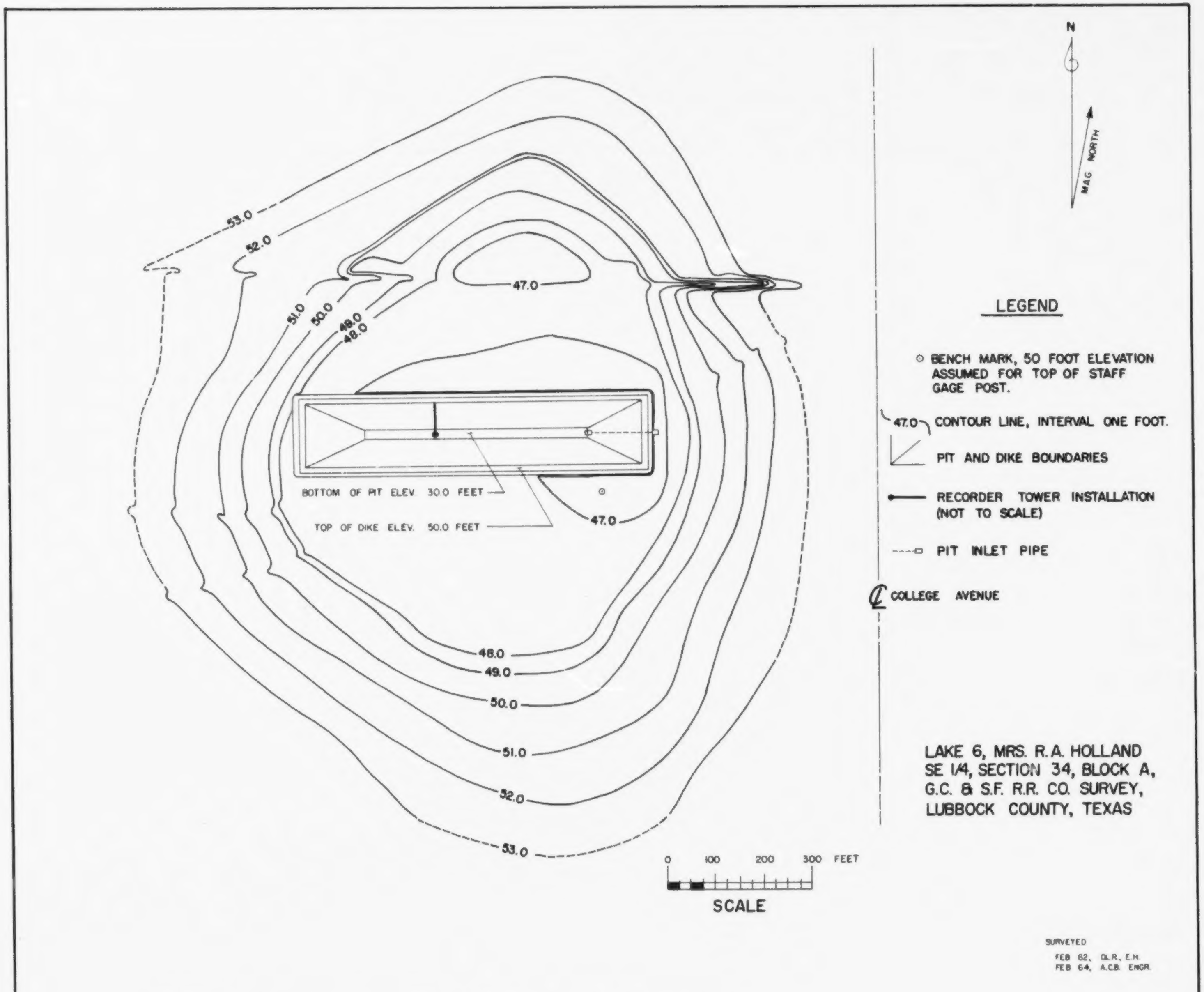
ELEVATION-AREA & ELEVATION-VOLUME CURVES, E.K. HUFSTEDLER, LAKE NO.3,
SE 1/4, SECTION 34, BLOCK A, G.C. & S.F. R.R. CO. SURVEY, LUBBOCK COUNTY, TEXAS

JUNE, 1964

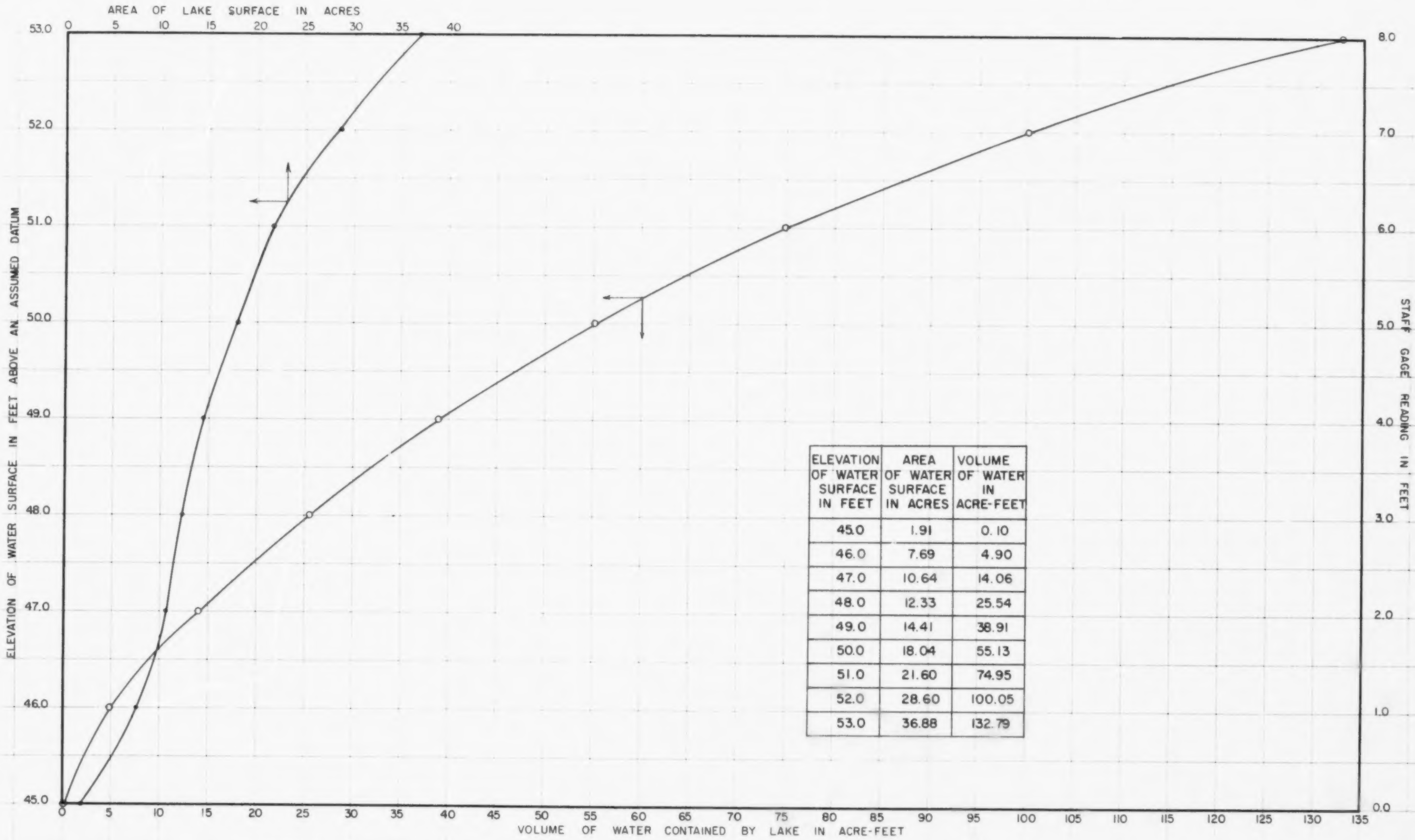


N
MAG NORTH
LEGEND
⊙ BENCH MARK, 50 FOOT ELEVATION ASSUMED FOR TOP OF STAFF GAGE POST.
47.0 CONTOUR LINE, INTERVAL ONE FOOT.
℄ COLLEGE AVENUE
LAKE 6, MRS. R. A. HOLLAND
SE 1/4, SECTION 34, BLOCK A,
G. C. & S. F. R. R. CO. SURVEY,
LUBBOCK COUNTY, TEXAS
45.0
46.0
47.0
48.0
49.0
50.0
51.0
52.0
53.0
0
100
200
300 FEET
SCALE
SURVEYED BY
D. L. REDDELL
E. HERSEY
FEB 10 & 11, 1962

PLAYA LAKE STUDY, LAKE NO. 6, LAND SURFACE CONFIGURATION


N
MAG NORTH
LEGEND
BENCH MARK, 50 FOOT ELEVATION ASSUMED FOR TOP OF STAFF GAGE POST.
47.0 CONTOUR LINE, INTERVAL ONE FOOT.
PIT AND DIKE BOUNDARIES
RECORDER TOWER INSTALLATION (NOT TO SCALE)
PIT INLET PIPE
COLLEGE AVENUE
LAKE 6, MRS. R.A. HOLLAND
SE 1/4, SECTION 34, BLOCK A,
G.C. & S.F. R.R. CO. SURVEY,
LUBBOCK COUNTY, TEXAS
BOTTOM OF PIT ELEV. 30.0 FEET
TOP OF DIKE ELEV. 50.0 FEET
47.0
48.0
49.0
50.0
51.0
52.0
53.0
0
100
200
300
FEET
SCALE
SURVEYED
FEB 62, D.L.R., E.H.
FEB 64, A.C.B. ENGR.

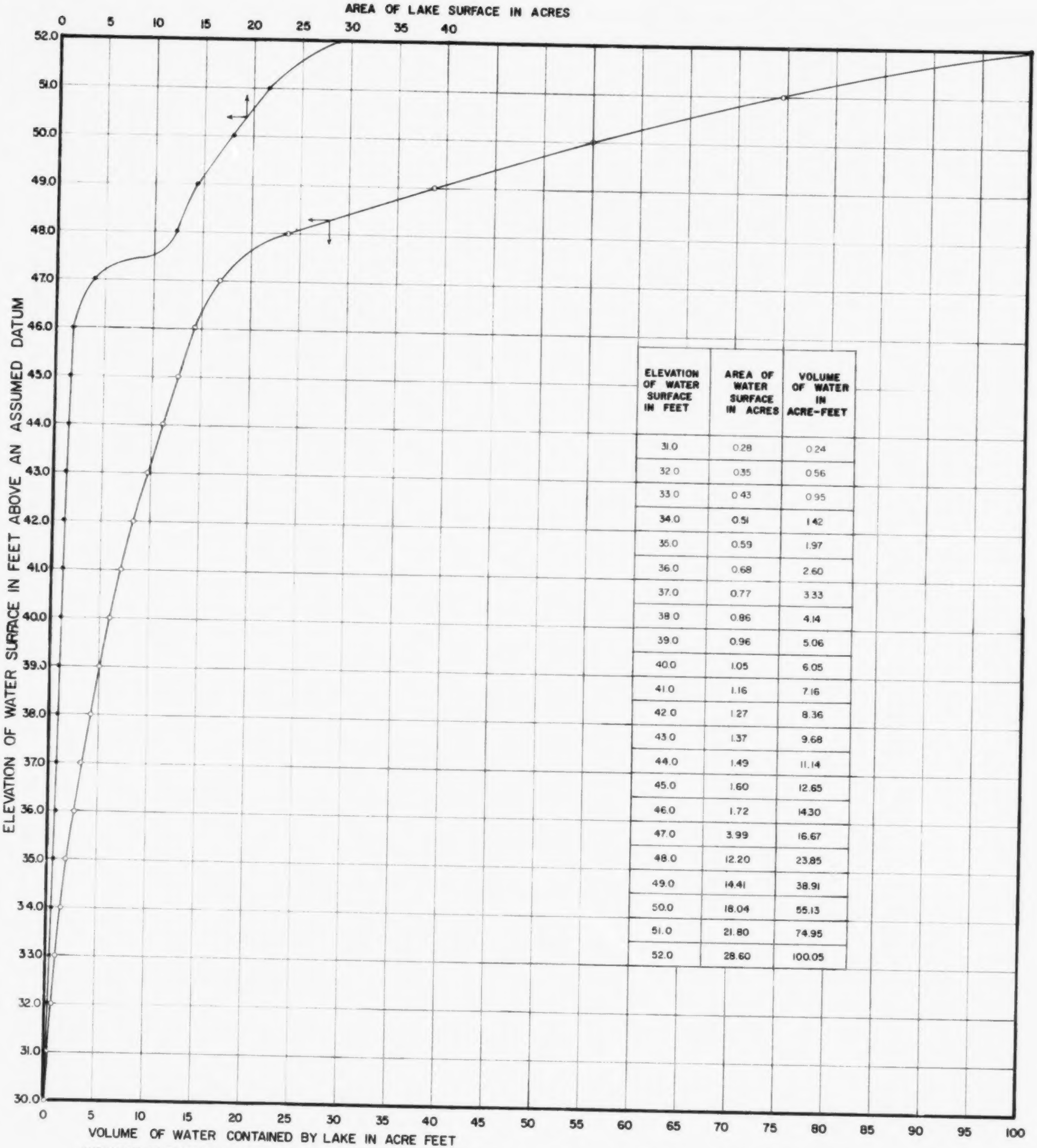
PLAYA LAKE STUDY, LAKE NO. 6, LAND SURFACE CONFIGURATION



ELEVATION OF WATER SURFACE IN FEET	AREA OF WATER SURFACE IN ACRES	VOLUME OF WATER IN ACRE-FEET
45.0	1.91	0.10
46.0	7.69	4.90
47.0	10.64	14.06
48.0	12.33	25.54
49.0	14.41	38.91
50.0	18.04	55.13
51.0	21.60	74.95
52.0	28.60	100.05
53.0	36.88	132.79

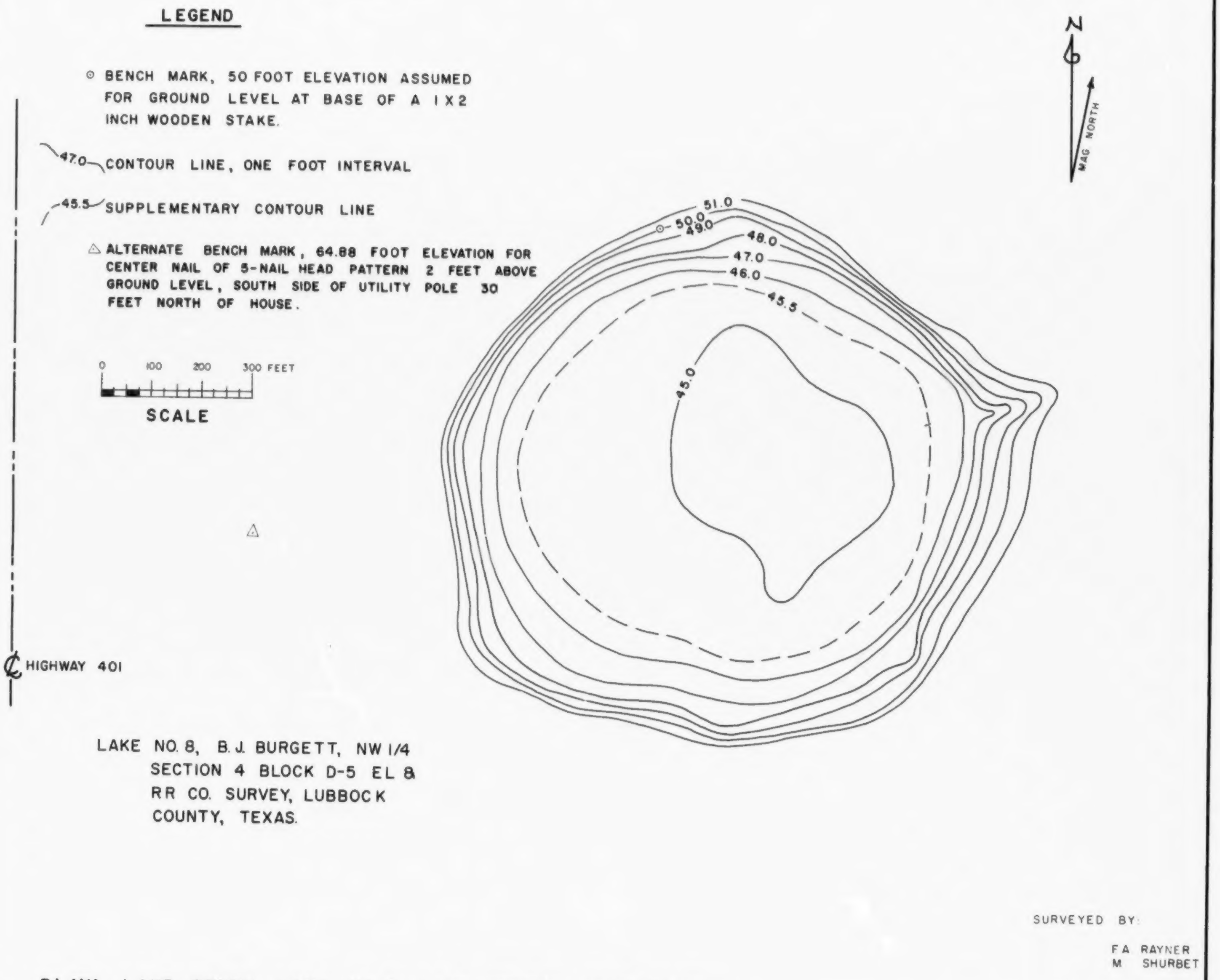
VOLUME-ELEVATION AND AREA-ELEVATION CURVES FOR LAKE NO.6 LOCATED IN THE SE 1/4 OF SECTION 34,
BLOCK A, G.C. & S.F. R.R. CO. SURVEY, LUBBOCK COUNTY, TEXAS

DRAWN BY: D. L. REDDELL
DATE: MAY 8, 1962



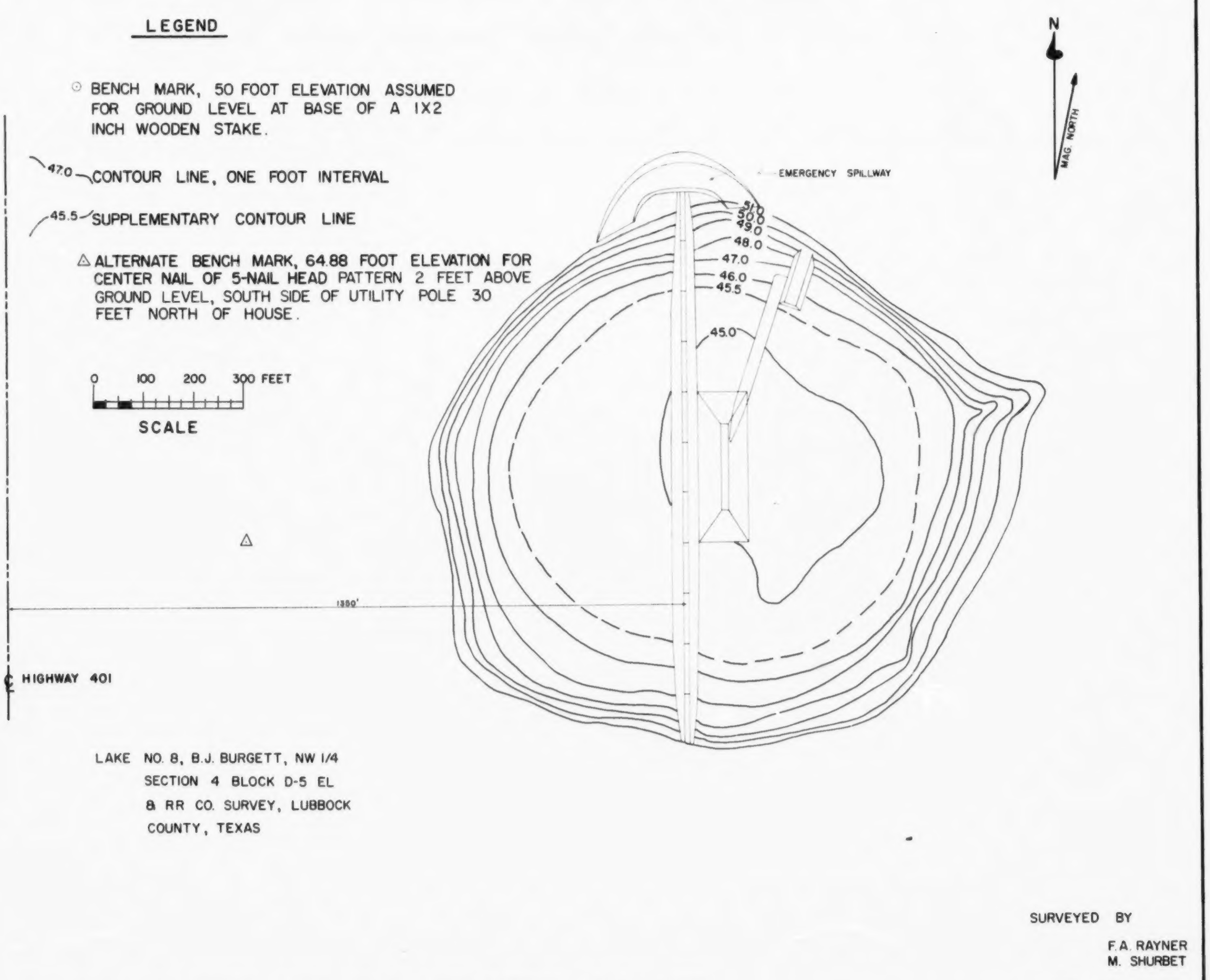
ELEVATION OF WATER SURFACE IN FEET	AREA OF WATER SURFACE IN ACRES	VOLUME OF WATER IN ACRE-FEET
31.0	0.28	0.24
32.0	0.35	0.56
33.0	0.43	0.95
34.0	0.51	1.42
35.0	0.59	1.97
36.0	0.68	2.60
37.0	0.77	3.33
38.0	0.86	4.14
39.0	0.96	5.06
40.0	1.05	6.05
41.0	1.16	7.16
42.0	1.27	8.36
43.0	1.37	9.68
44.0	1.49	11.14
45.0	1.60	12.65
46.0	1.72	14.30
47.0	3.99	16.67
48.0	12.20	23.85
49.0	14.41	38.91
50.0	18.04	55.13
51.0	21.80	74.95
52.0	28.60	100.05

VOLUME-ELEVATION AND AREA-ELEVATION CURVES FOR LAKE NO. 6 LOCATED IN THE SE 1/4 OF SECTION 34, BLOCK A, G.C. & S.F. R.R. CO. SURVEY, LUBBOCK COUNTY, TEXAS

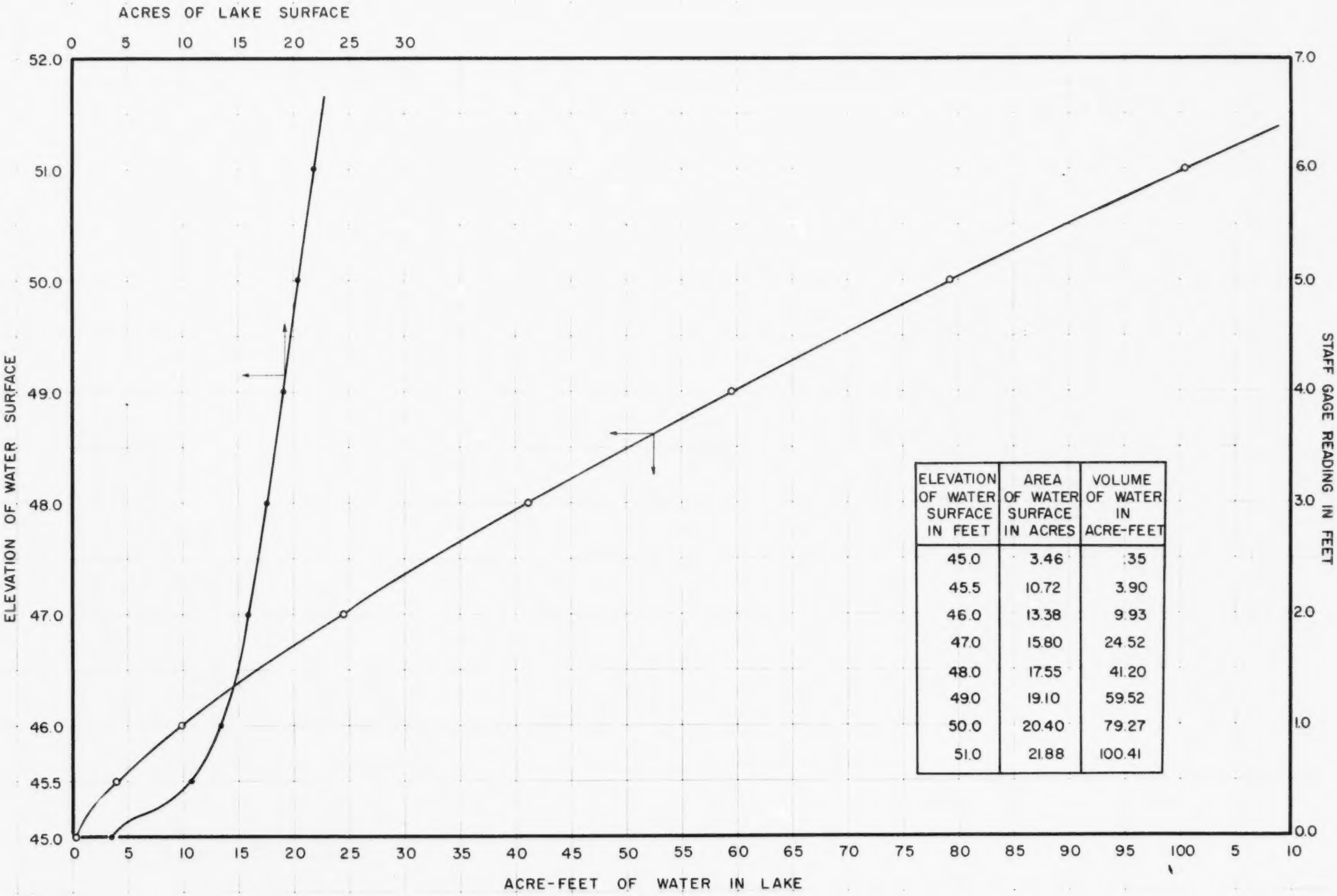

LEGEND
⊙ BENCH MARK, 50 FOOT ELEVATION ASSUMED FOR GROUND LEVEL AT BASE OF A 1 X 2 INCH WOODEN STAKE.
47.0 CONTOUR LINE, ONE FOOT INTERVAL
45.5 SUPPLEMENTARY CONTOUR LINE
△ ALTERNATE BENCH MARK, 64.88 FOOT ELEVATION FOR CENTER NAIL OF 5-NAIL HEAD PATTERN 2 FEET ABOVE GROUND LEVEL, SOUTH SIDE OF UTILITY POLE 30 FEET NORTH OF HOUSE.
0
100
200
300 FEET
SCALE
N
MAG NORTH
51.0
50.0
49.0
48.0
47.0
46.0
45.5
45.0
℄ HIGHWAY 401
LAKE NO. 8, B. J. BURGETT, NW 1/4 SECTION 4 BLOCK D-5 EL & RR CO. SURVEY, LUBBOCK COUNTY, TEXAS.
SURVEYED BY:
F A RAYNER
M SHURBET

PLAYA LAKE STUDY, LAKE NO. 8, LAND SURFACE CONFIGURATION

MARCH 4, 1962


LEGEND
⊙ BENCH MARK, 50 FOOT ELEVATION ASSUMED FOR GROUND LEVEL AT BASE OF A 1X2 INCH WOODEN STAKE.
47.0 CONTOUR LINE, ONE FOOT INTERVAL
45.5 SUPPLEMENTARY CONTOUR LINE
△ ALTERNATE BENCH MARK, 64.88 FOOT ELEVATION FOR CENTER NAIL OF 5-NAIL HEAD PATTERN 2 FEET ABOVE GROUND LEVEL, SOUTH SIDE OF UTILITY POLE 30 FEET NORTH OF HOUSE.
0
100
200
300 FEET
SCALE
N
MAG. NORTH
EMERGENCY SPILLWAY
51.0
50.0
49.0
48.0
47.0
46.0
45.5
45.0
1350'
℄ HIGHWAY 401
LAKE NO. 8, B.J. BURGETT, NW 1/4 SECTION 4 BLOCK D-5 EL & RR CO. SURVEY, LUBBOCK COUNTY, TEXAS
SURVEYED BY
F.A. RAYNER
M. SHURBET
AUGUST 1964

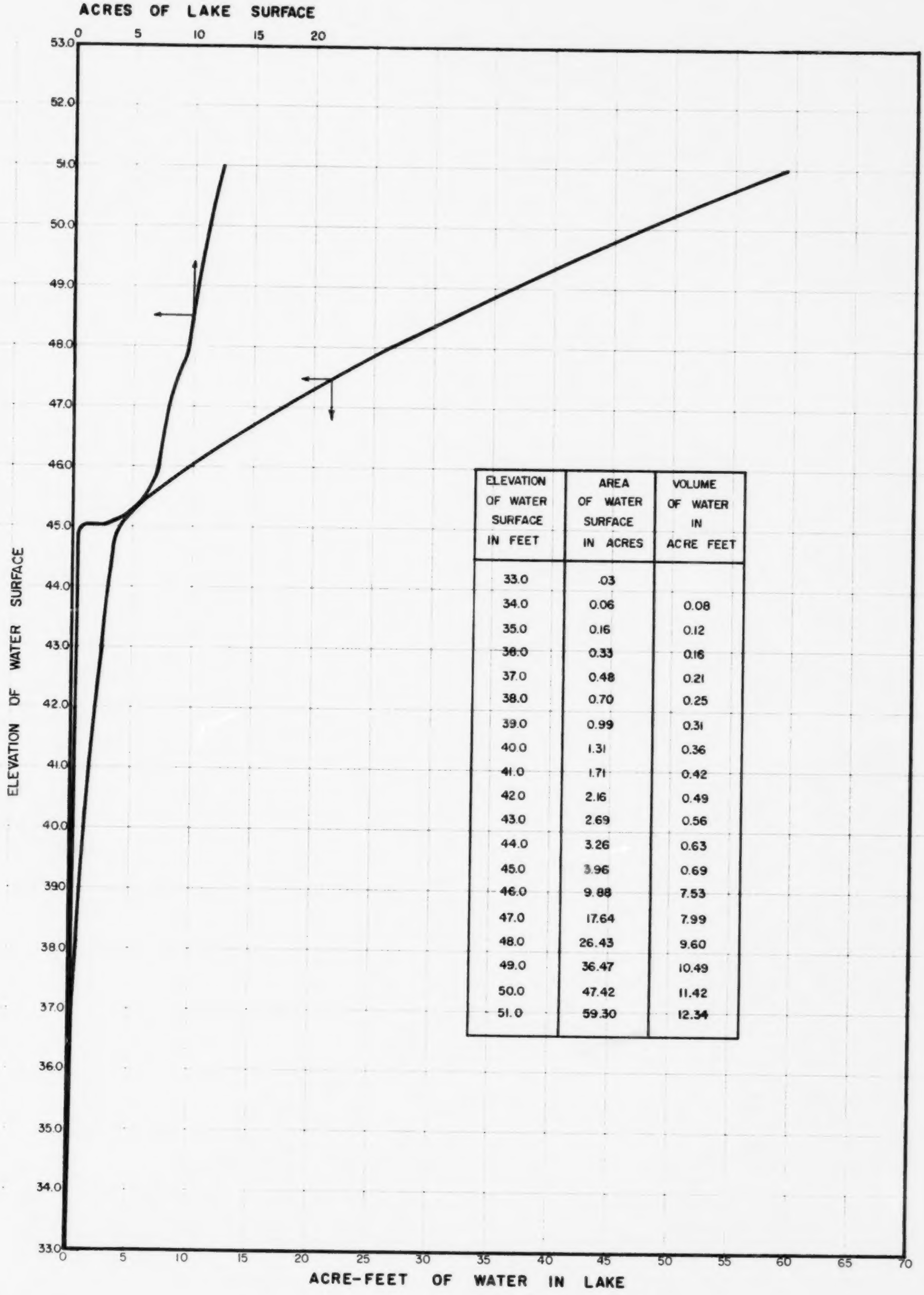
PLAYA LAKE STUDY, LAKE NO. 8, LAND SURFACE CONFIGURATION



ELEVATION OF WATER SURFACE IN FEET	AREA OF WATER SURFACE IN ACRES	VOLUME OF WATER IN ACRE-FEET
45.0	3.46	.35
45.5	10.72	3.90
46.0	13.38	9.93
47.0	15.80	24.52
48.0	17.55	41.20
49.0	19.10	59.52
50.0	20.40	79.27
51.0	21.88	100.41

ELEVATION-AREA & ELEVATION-VOLUME CURVES FOR LAKE NO. 8, IN THE NW 1/4 OF SECTION 4, BLOCK D-5, EL & RR CO SURVEY, LUBBOCK COUNTY, TEXAS.

DRAWN BY:
FA RAYNER
APR 22, 1962



ELEVATION OF WATER SURFACE IN FEET	AREA OF WATER SURFACE IN ACRES	VOLUME OF WATER IN ACRE FEET
33.0	.03	
34.0	0.06	0.08
35.0	0.16	0.12
36.0	0.33	0.16
37.0	0.48	0.21
38.0	0.70	0.25
39.0	0.99	0.31
40.0	1.31	0.36
41.0	1.71	0.42
42.0	2.16	0.49
43.0	2.69	0.56
44.0	3.26	0.63
45.0	3.96	0.69
46.0	9.88	7.53
47.0	17.64	7.99
48.0	26.43	9.60
49.0	36.47	10.49
50.0	47.42	11.42
51.0	59.30	12.34

ELEVATION-AREA & ELEVATION-VOLUME CURVES FOR LAKE NO.8, IN THE NW 1/4 OF SECTION 4, BLOCK D-5, EL & RR CO SURVEY, LUBBOCK COUNTY, TEXAS

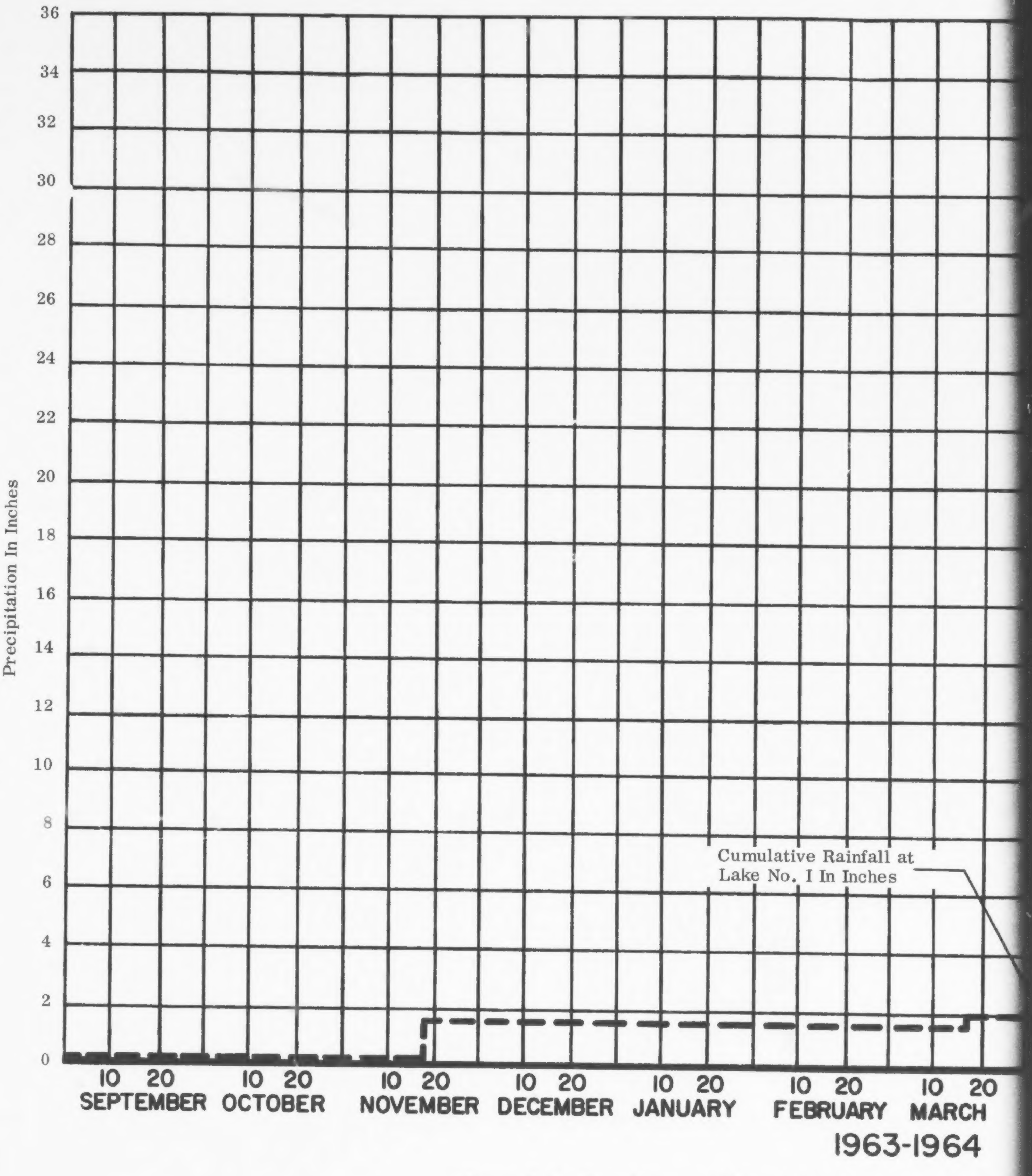
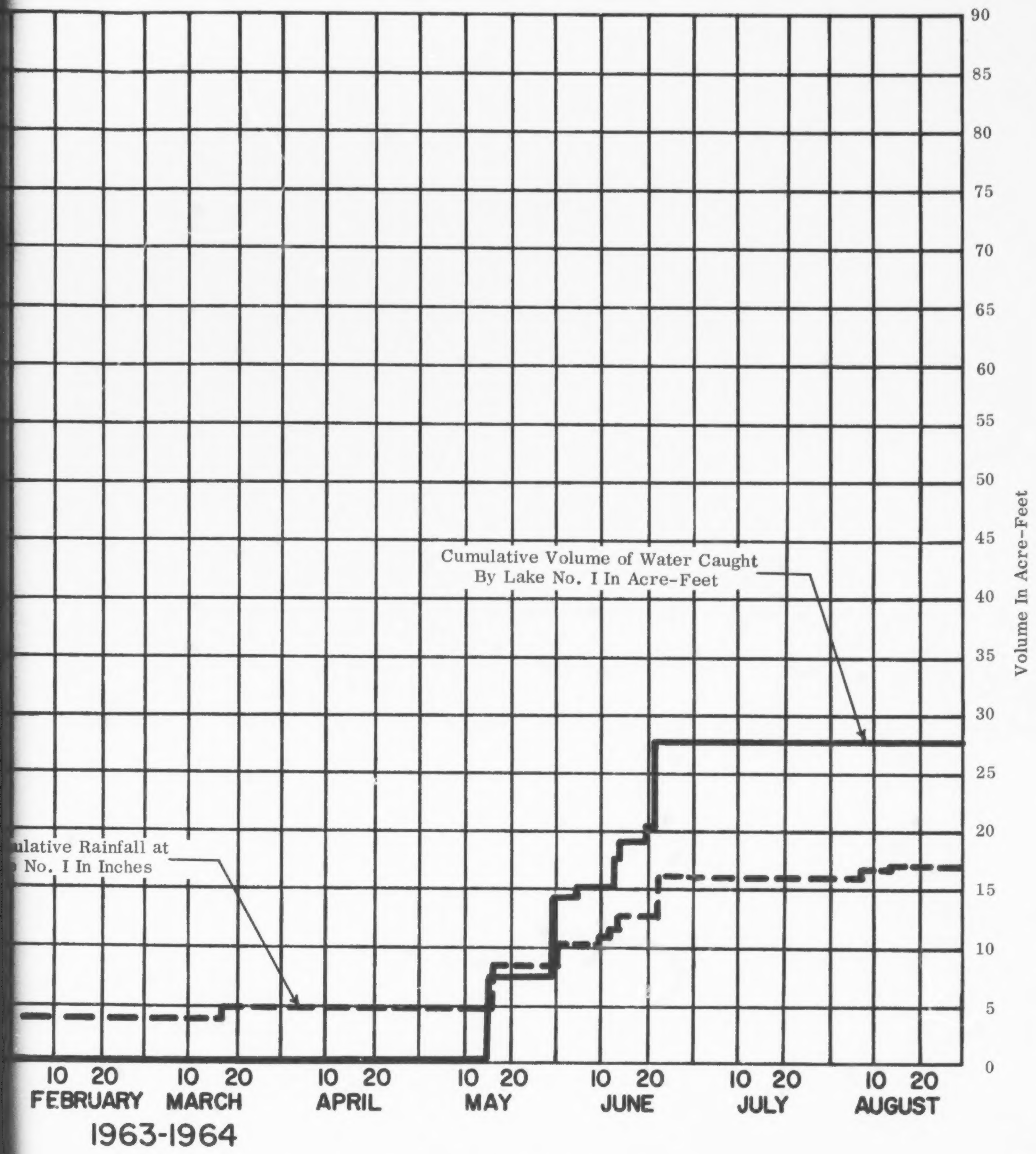


Figure II-1. Cumulative Rainfall and Cumulative Volume of Wa



and Cumulative Volume of Water Caught By Lake No. I (Huckabee).

APPENDIX II.

Daily Curves and Cumulative Curves on Each Lake

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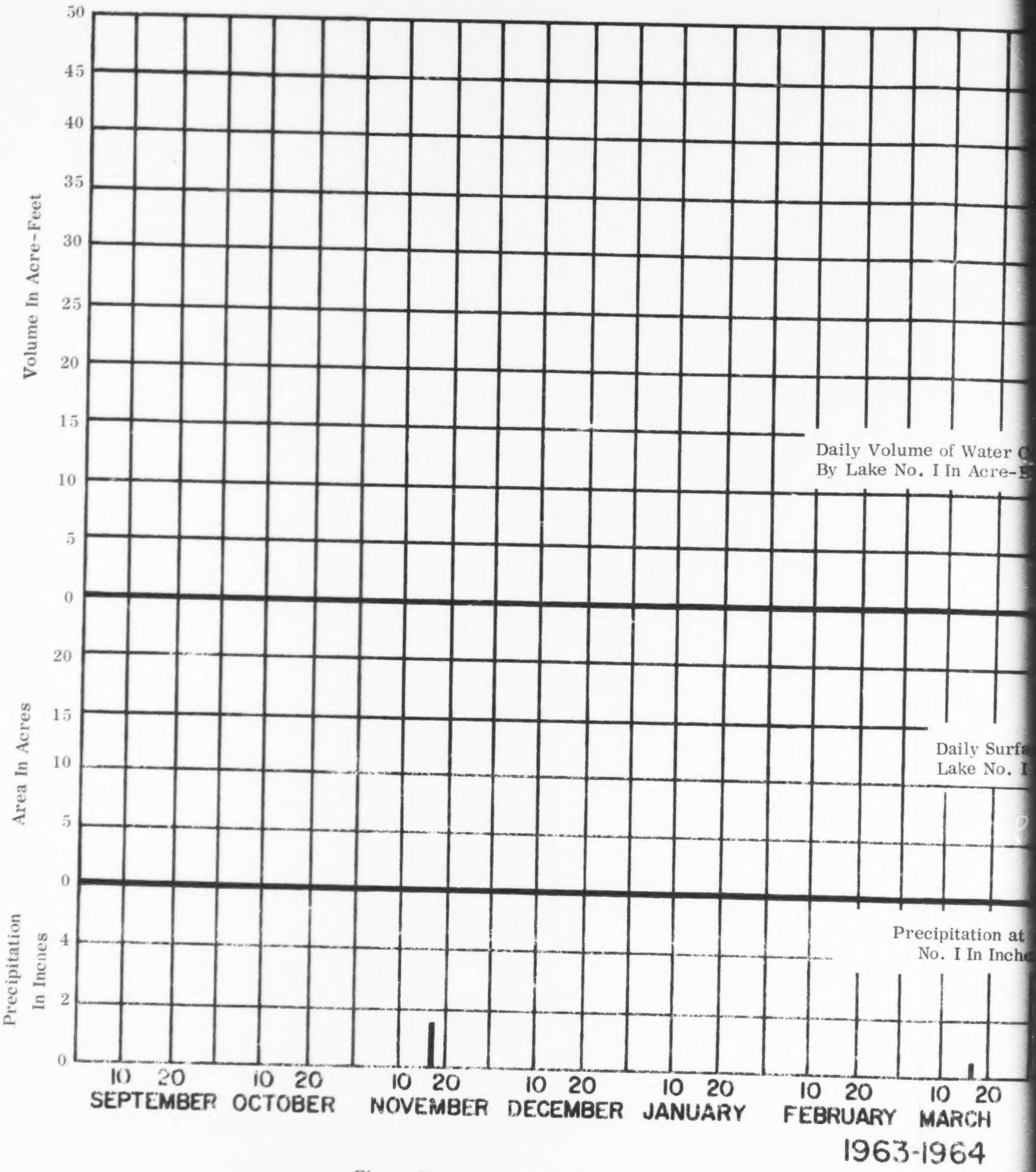
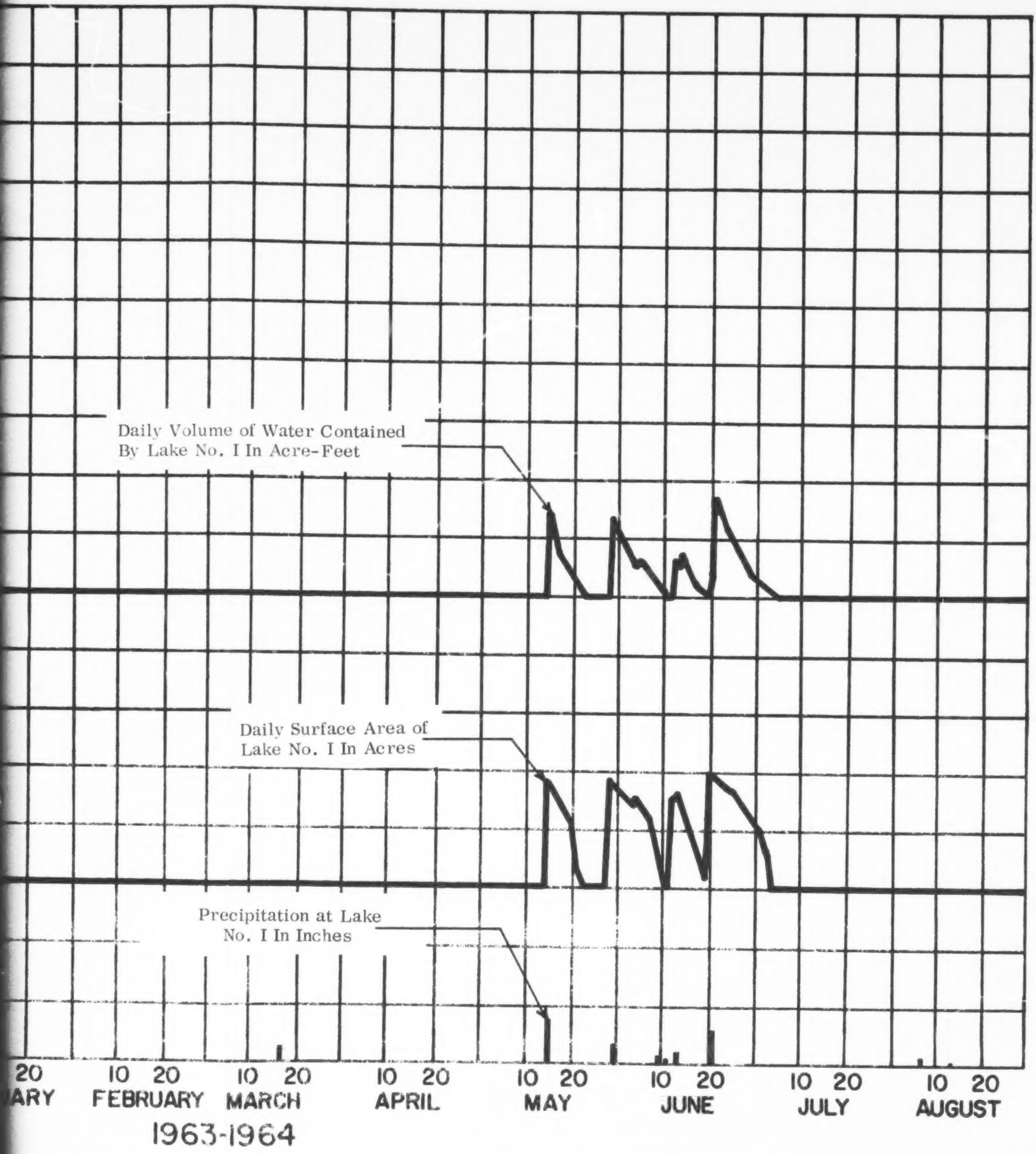


Figure II-2. Daily Volume of Water Contained By Lake, Daily Surface Area



ntained By Lake, Daily Surface Area of Lake and Precipitation at Lake No. I (Huckabee).

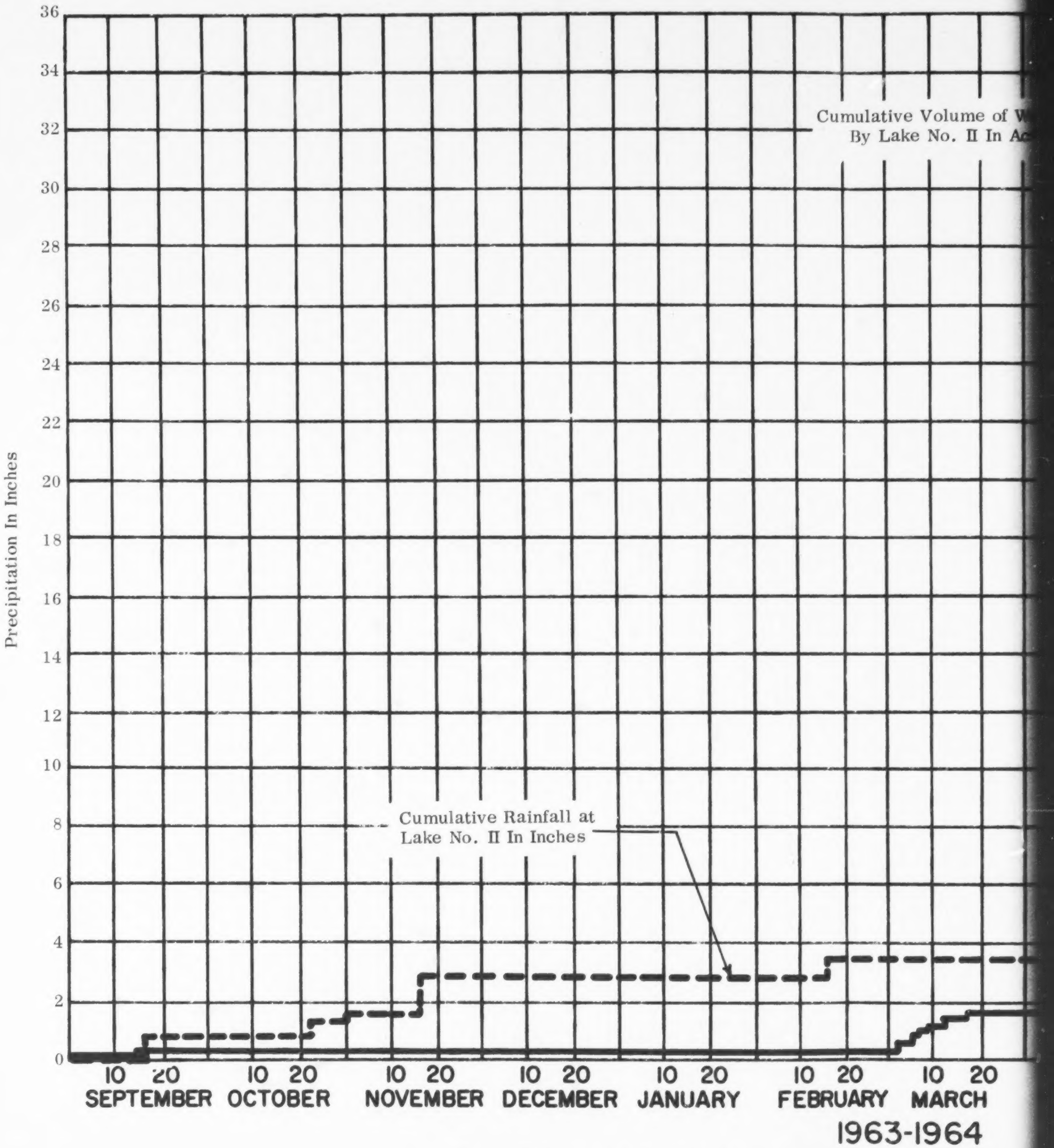
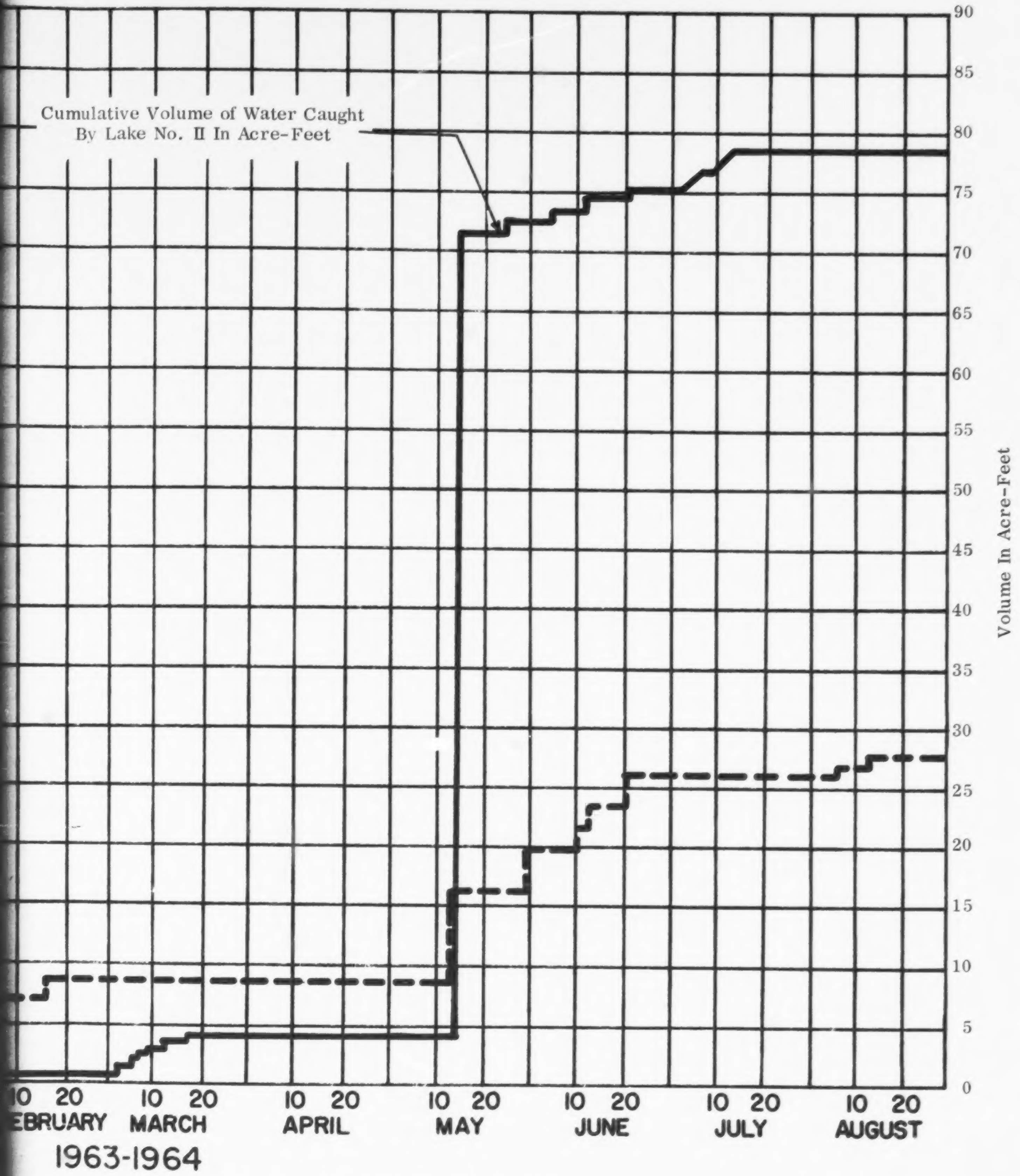


Figure II-3. Cumulative Rainfall and Cumulative Volume of Water



umulative Volume of Water Caught By Lake No. II (Knowles).

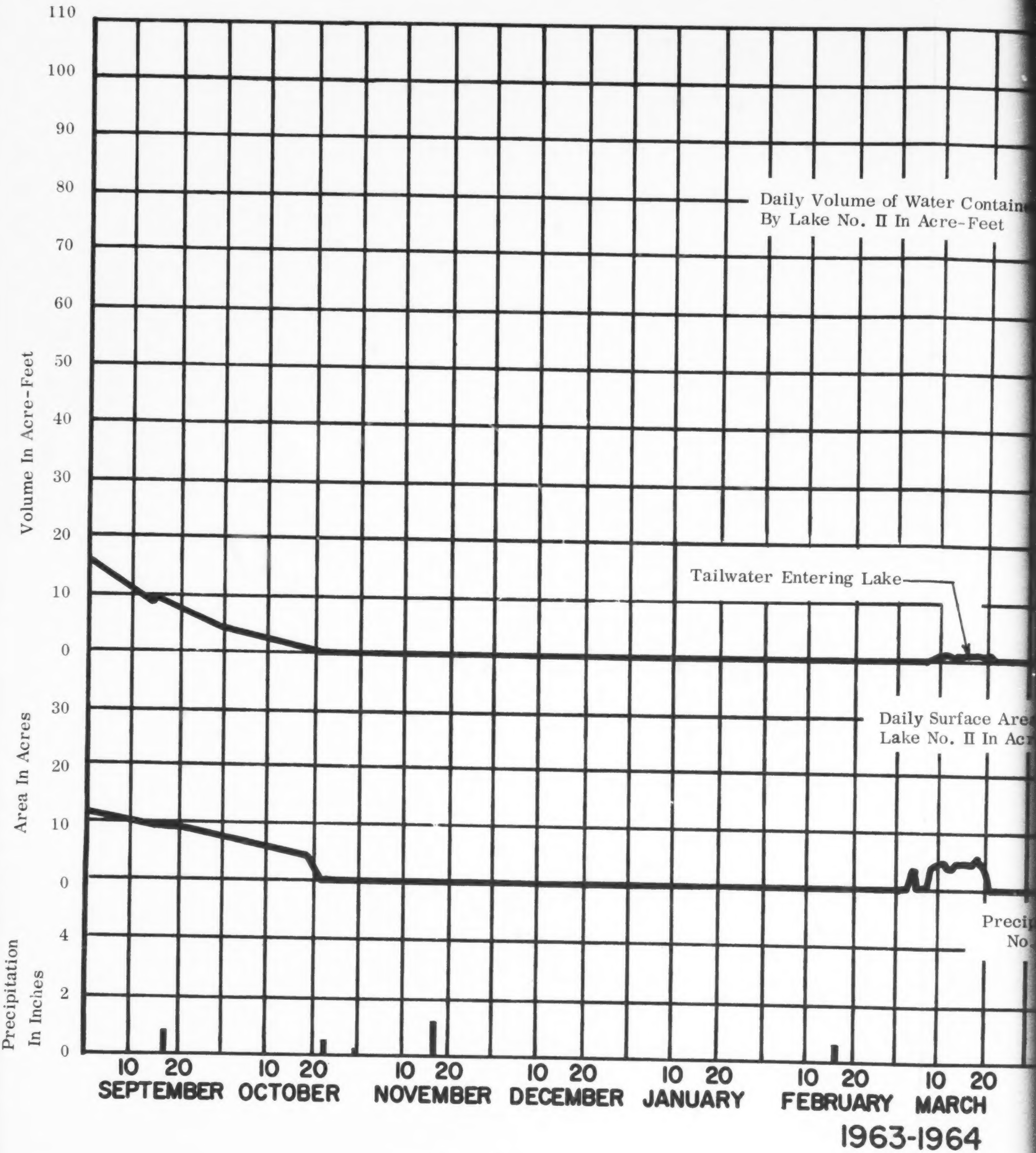
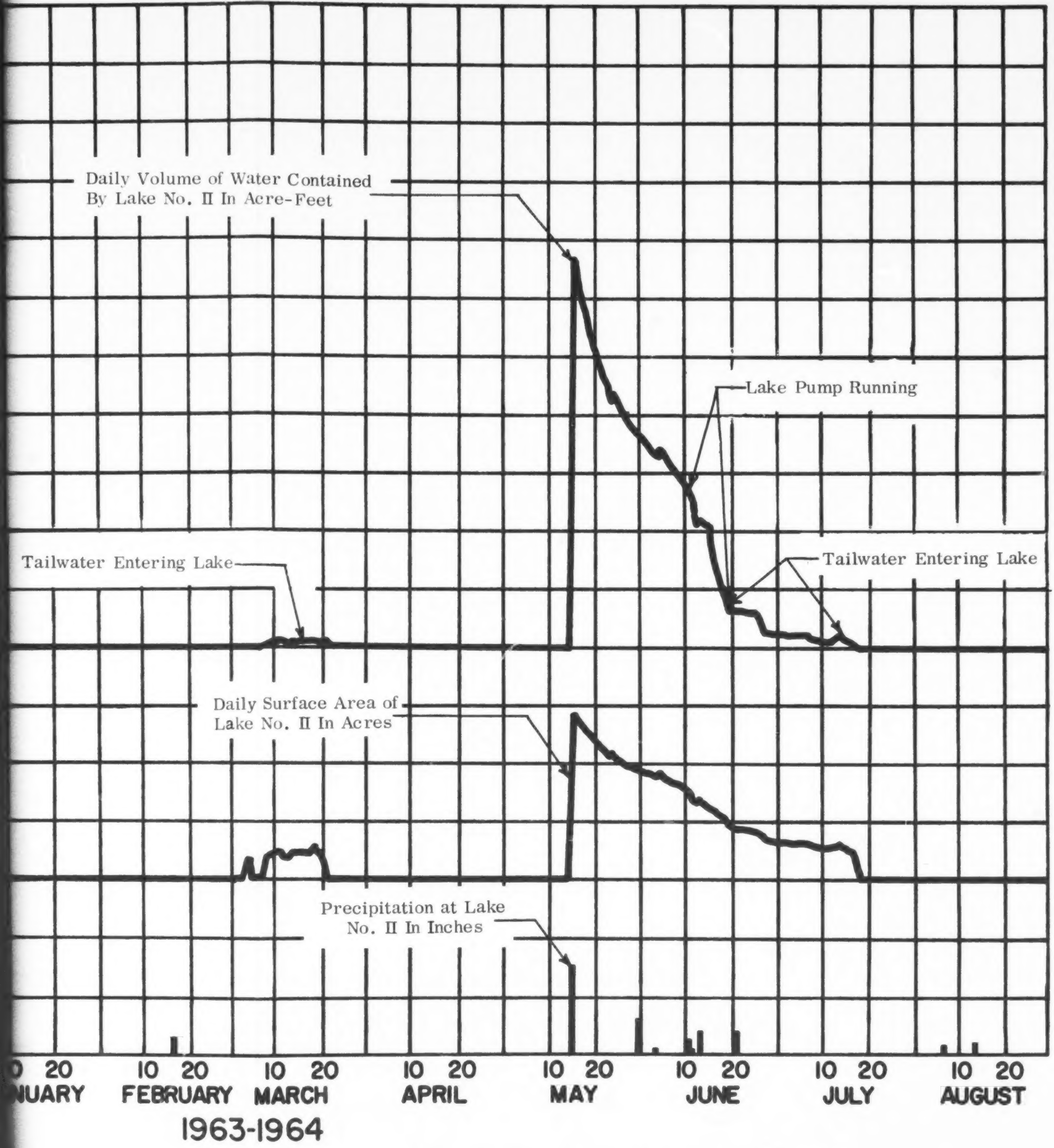


Figure II-4. Daily Volume of Water Contained By Lake, Daily Surface Are



ter Contained By Lake, Daily Surface Area of Lake and Precipitation of Lake No. II (Knowles).

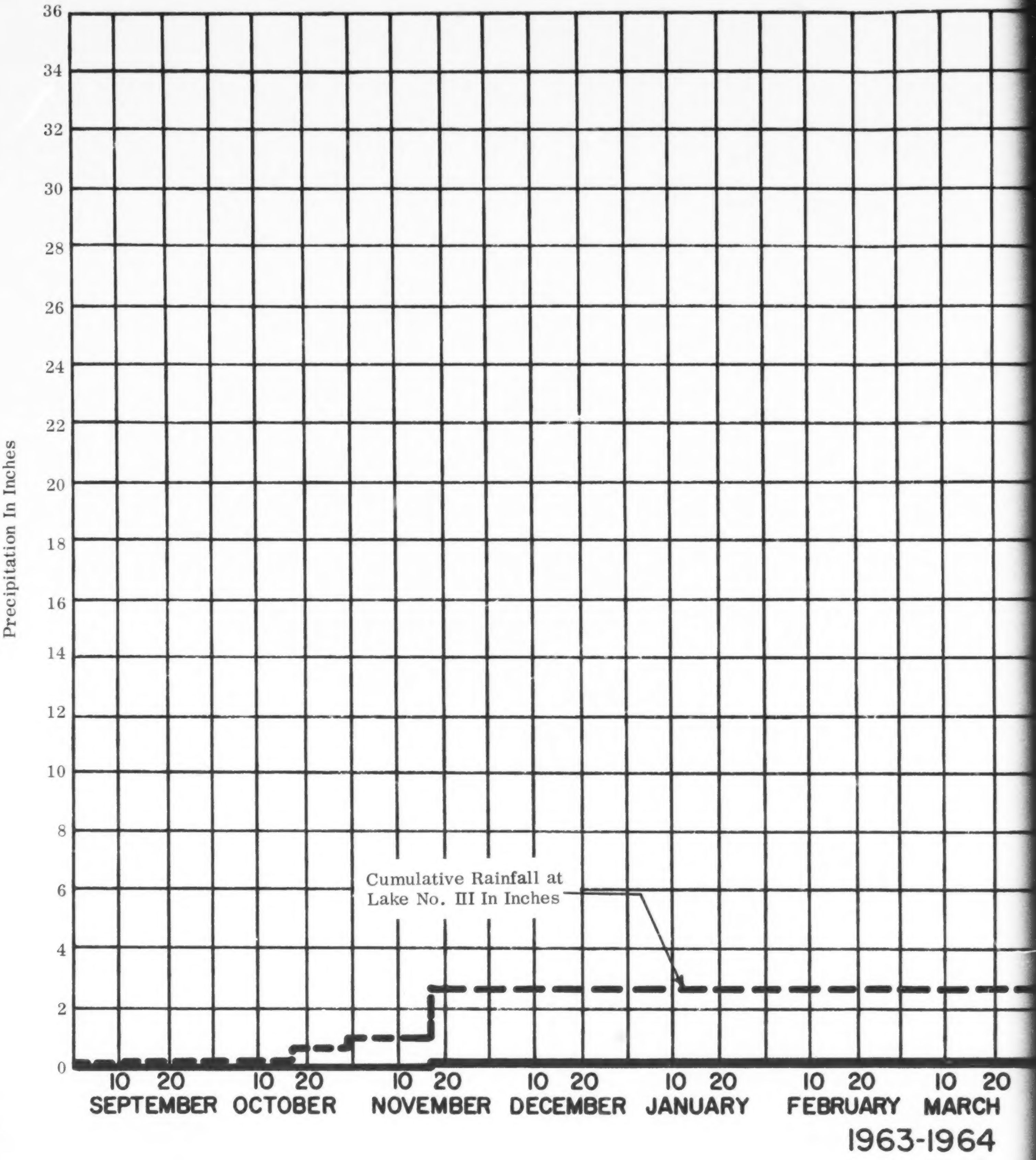
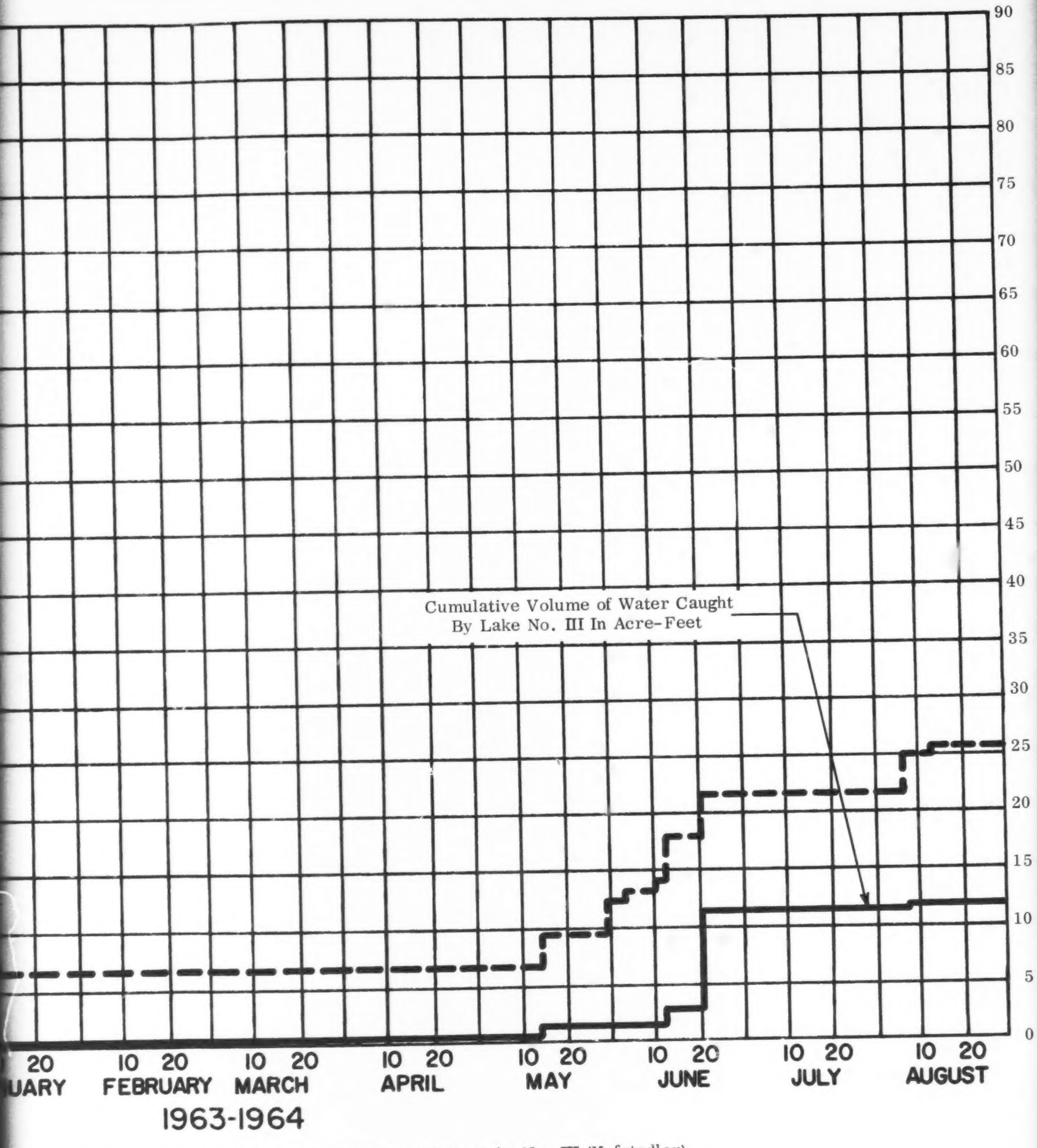


Figure II-5. Cumulative Rainfall and Cumulative Volume of W



e Rainfall and Cumulative Volume of Water Caught By Lake No. III (Hufstedler).

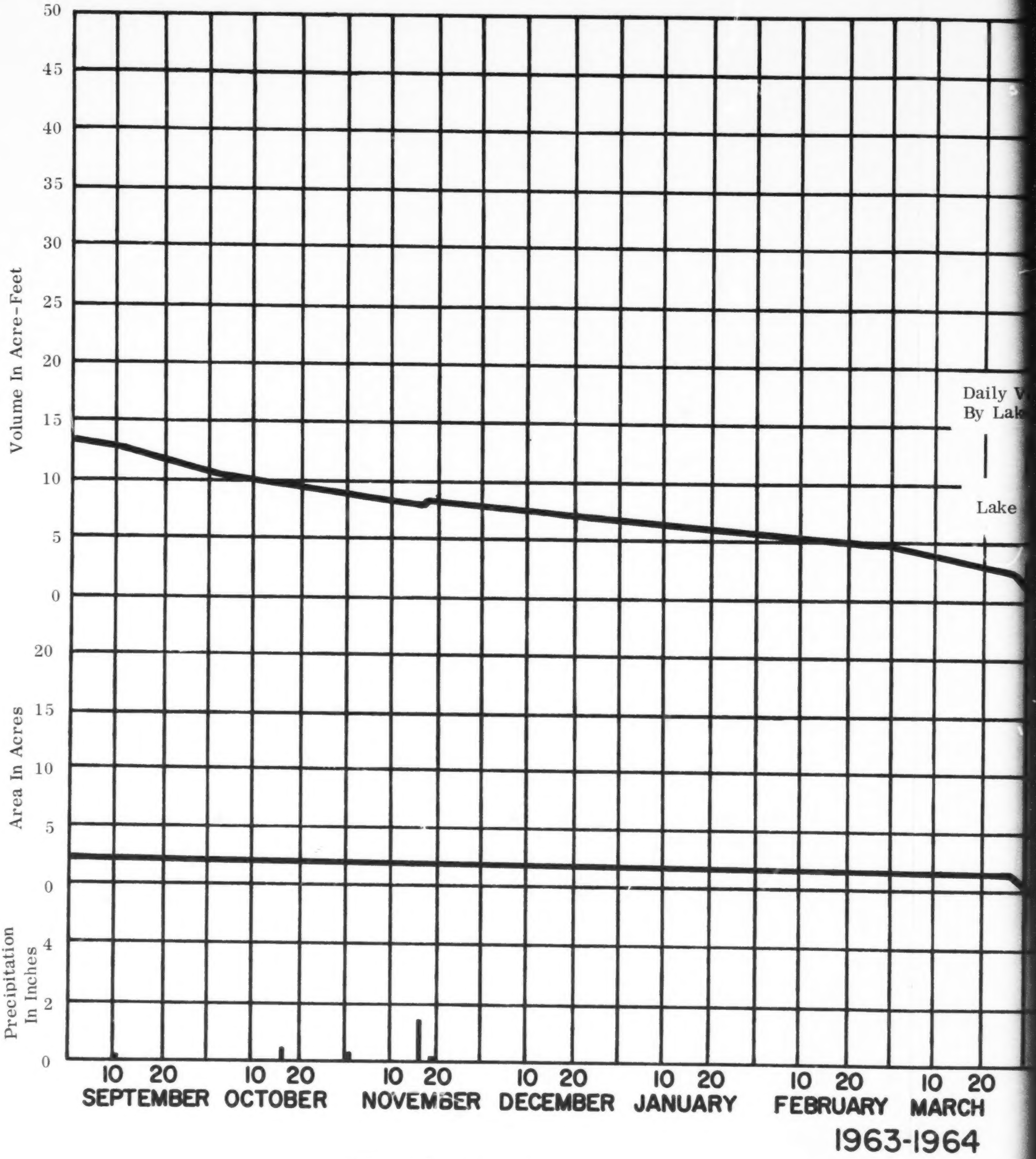
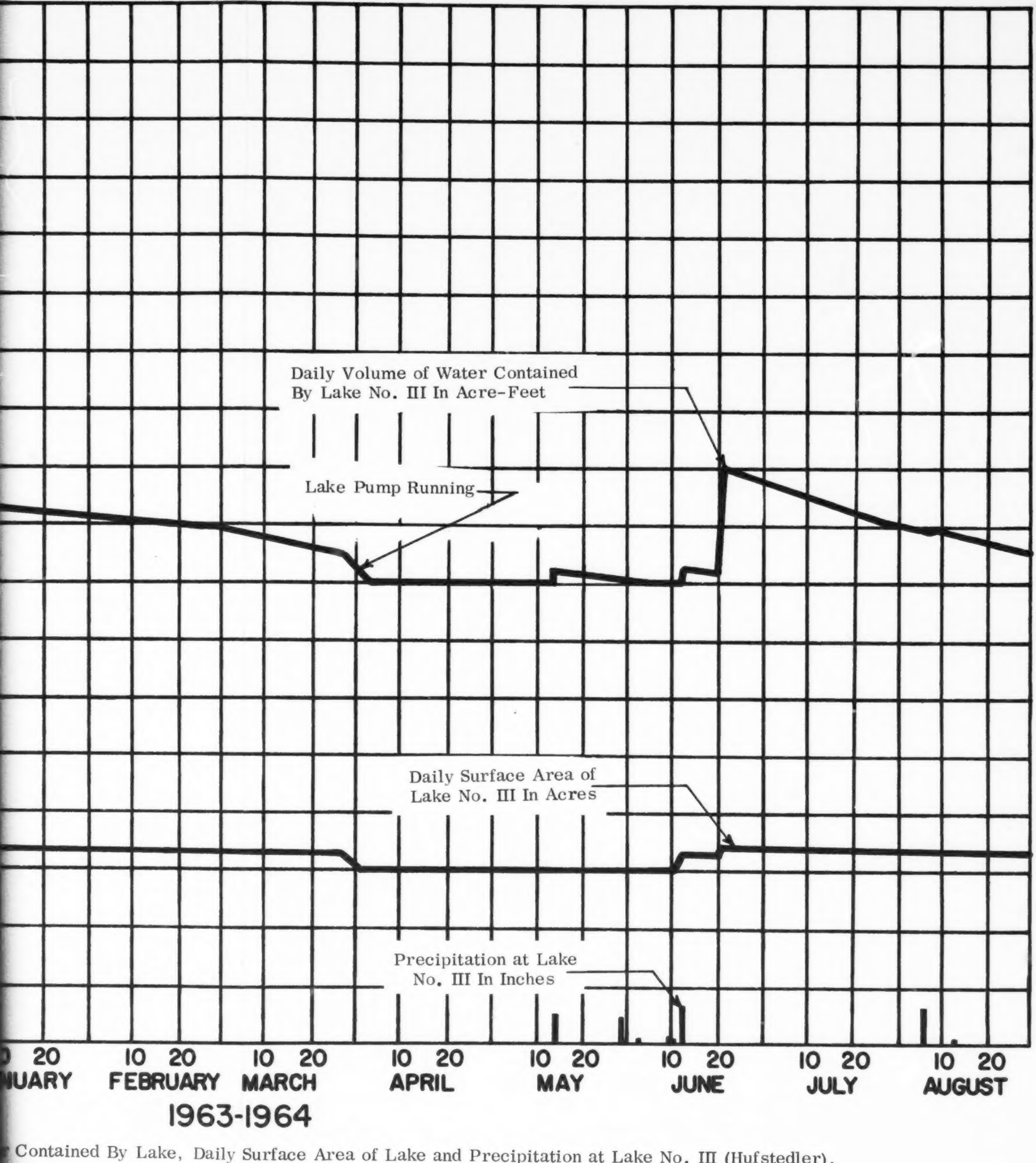


Figure II-6. Daily Volume of Water Contained By Lake, Daily Surface Area



Contained By Lake, Daily Surface Area of Lake and Precipitation at Lake No. III (Hufstedler).

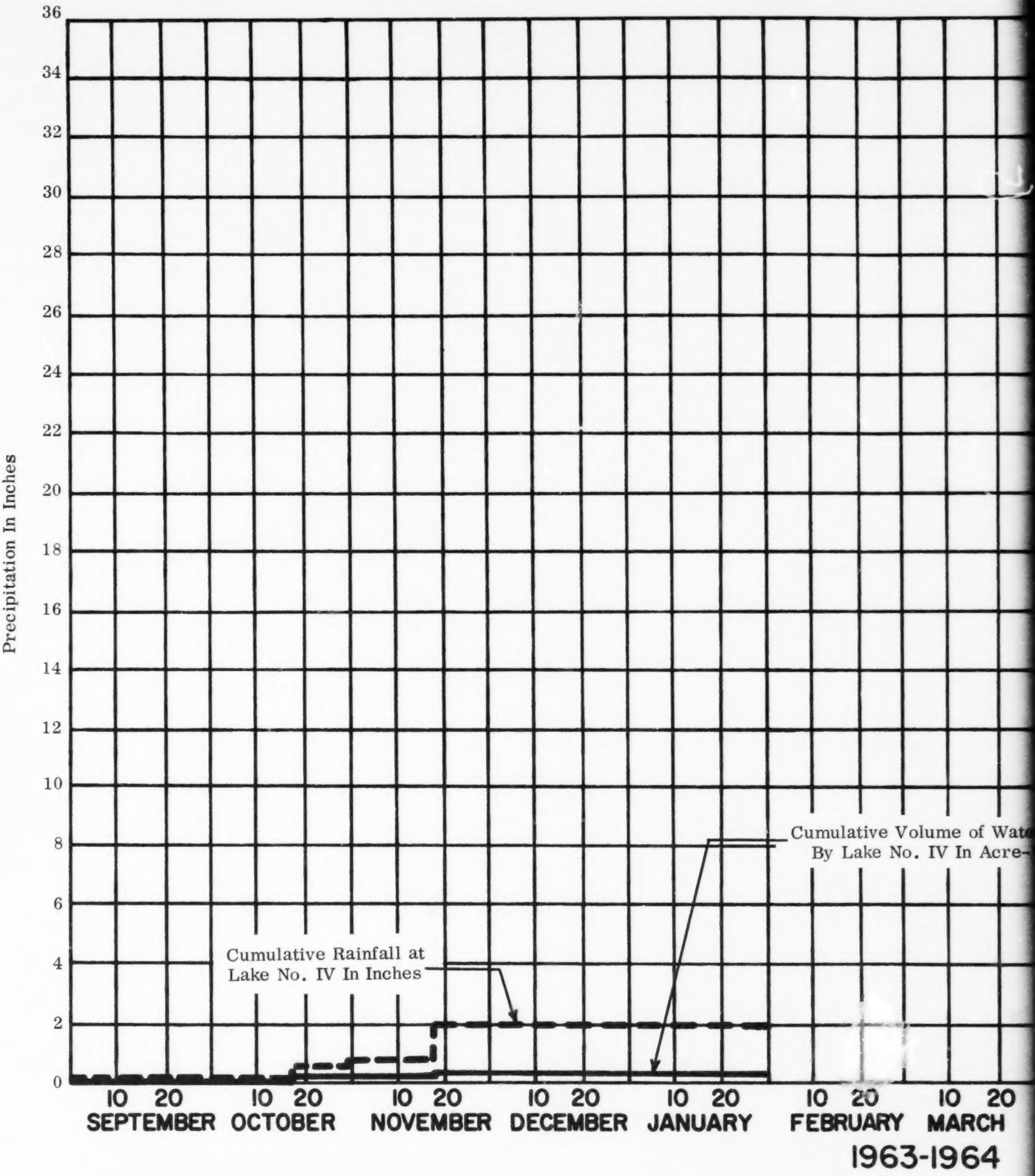
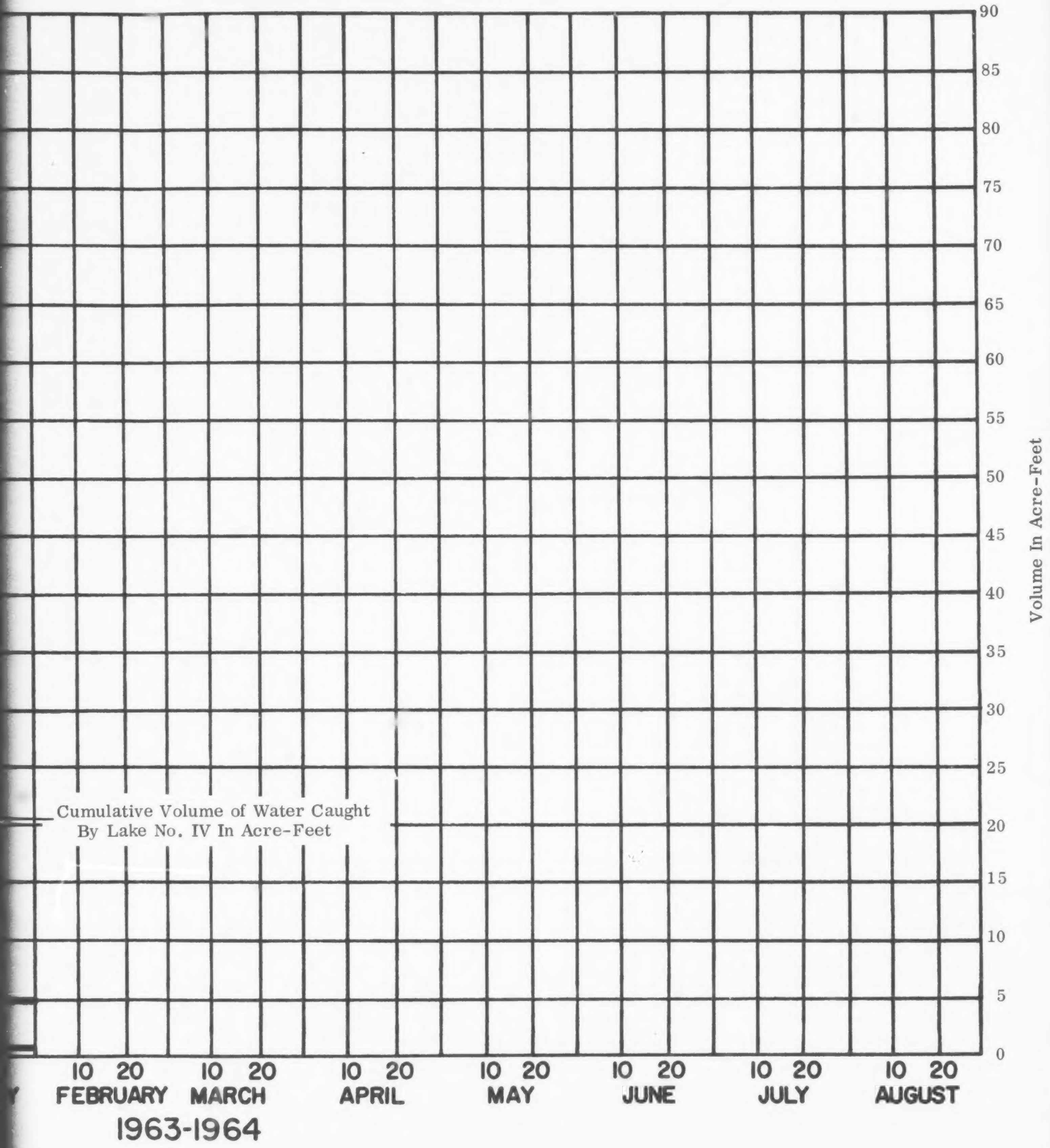


Figure II-7. Cumulative Rainfall and Cumulative Volume of Wa



l and Cumulative Volume of Water Caught By Lake No. IV (L.C.C.).

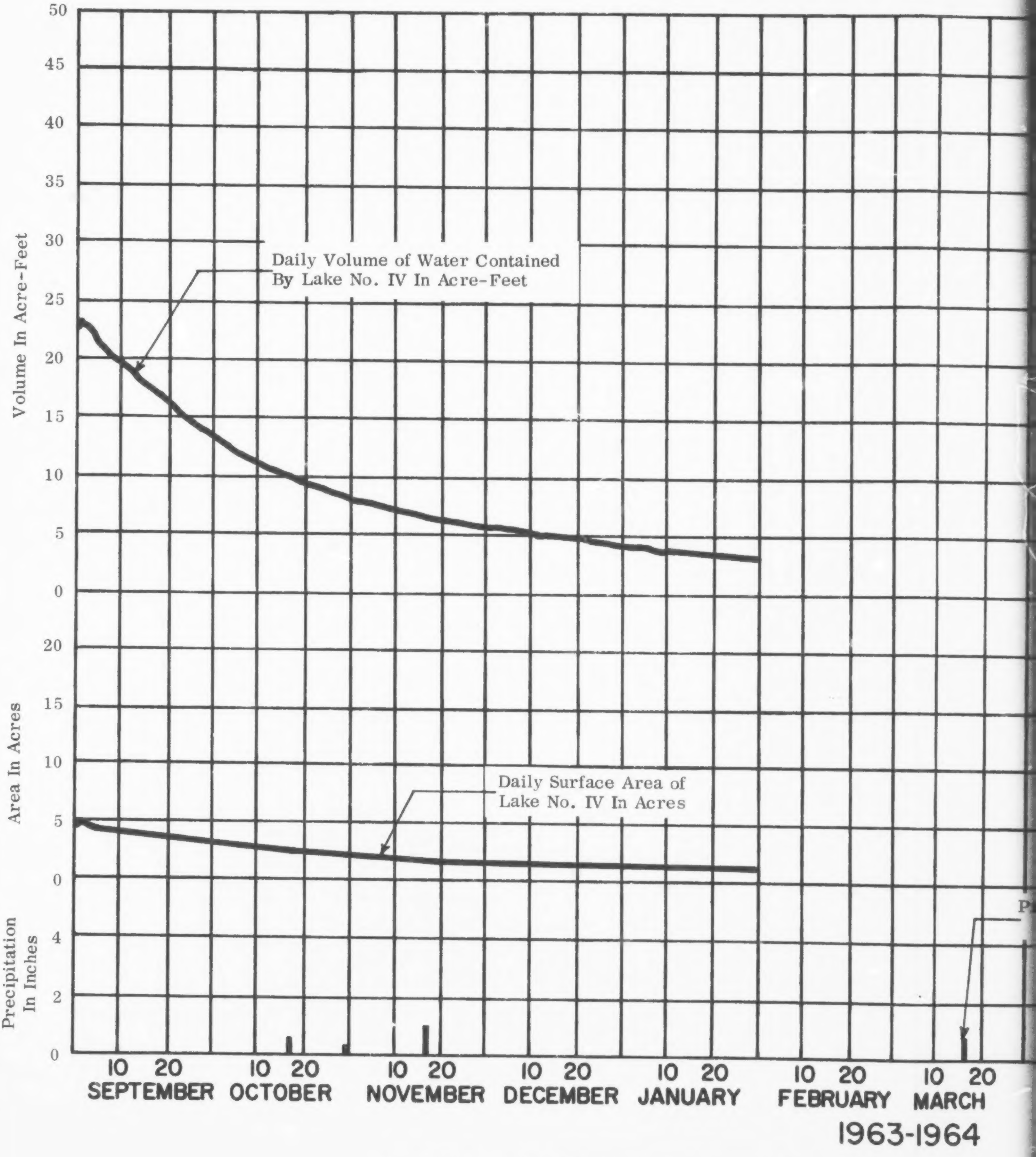
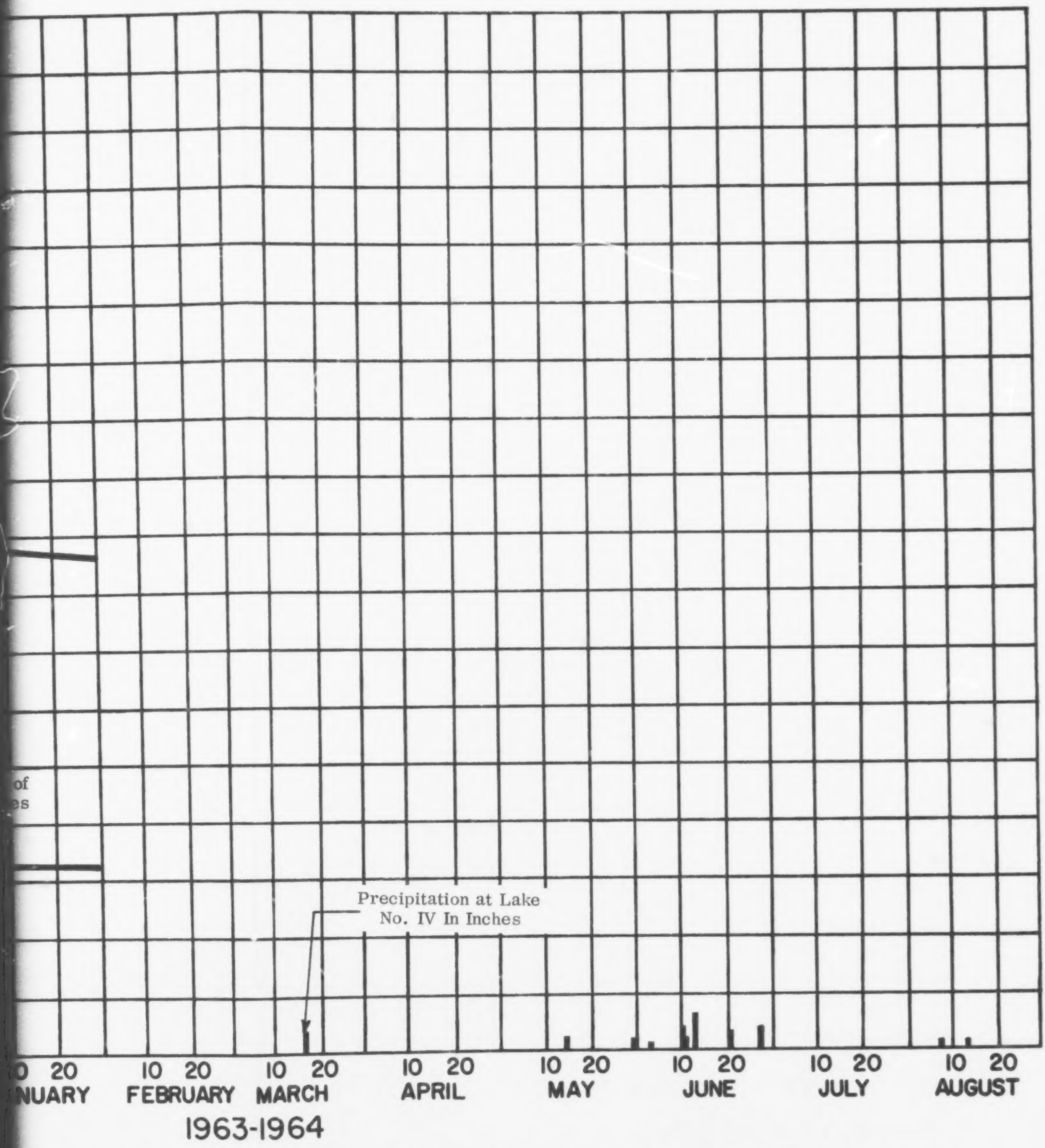


Figure II-8. Daily Volume of Water Contained By Lake, Daily Surface Are



ter Contained By Lake, Daily Surface Area of Lake and Precipitation at Lake No. IV (L.C.C.).

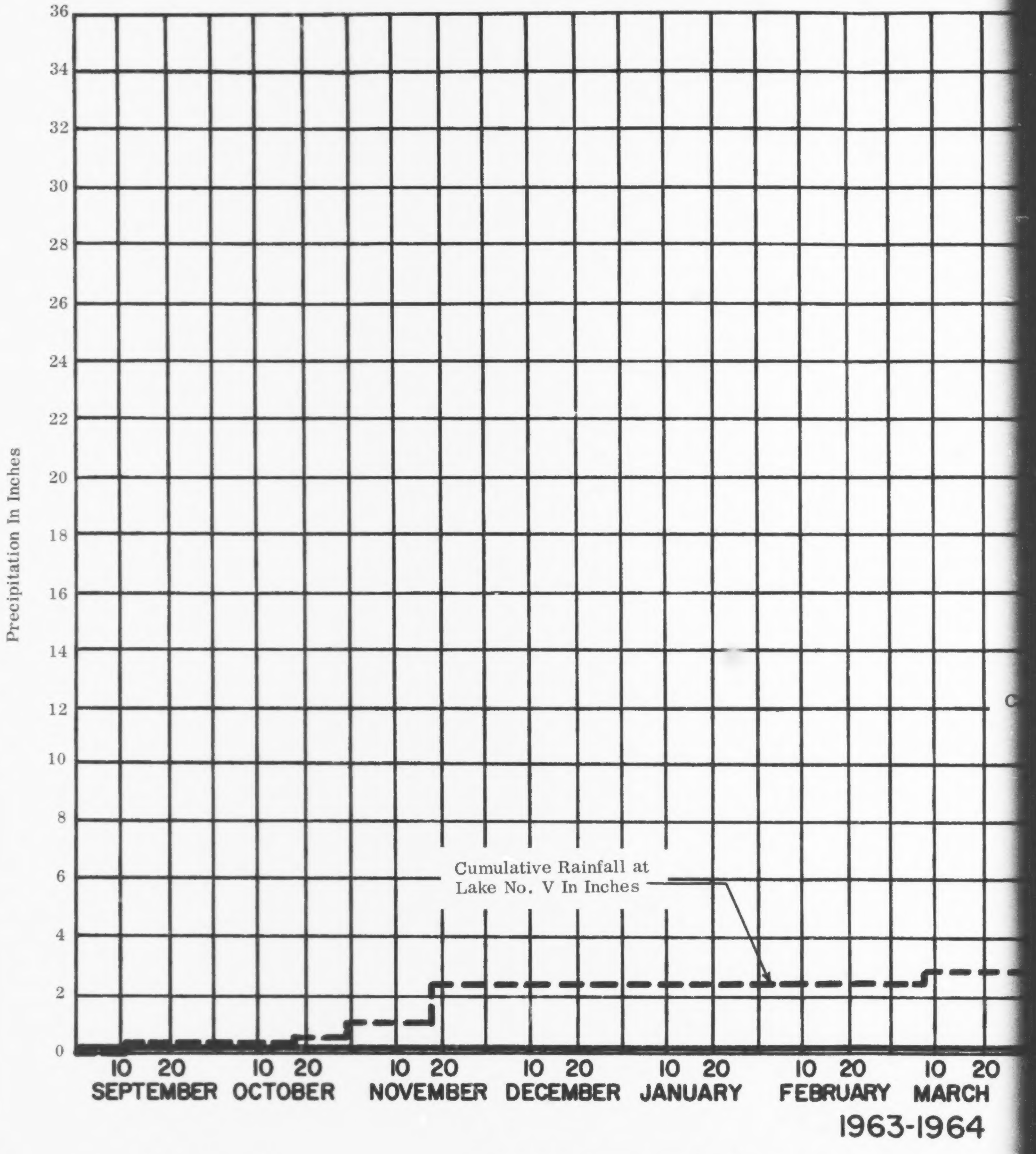
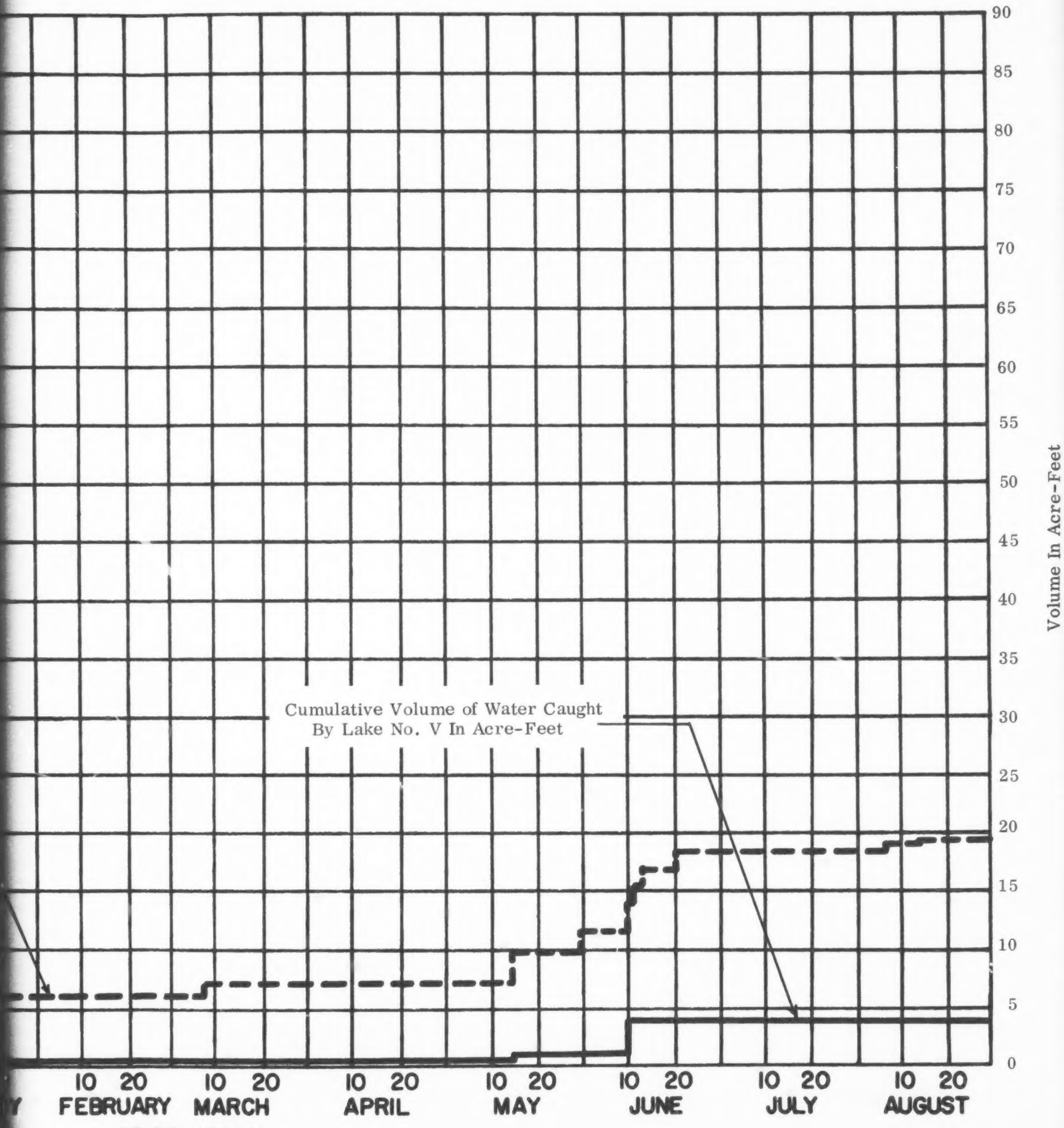


Figure II-9. Cumulative Rainfall and Cumulative Volume of W



all and Cumulative Volume of Water Caught By Lake No. V (Kitten).

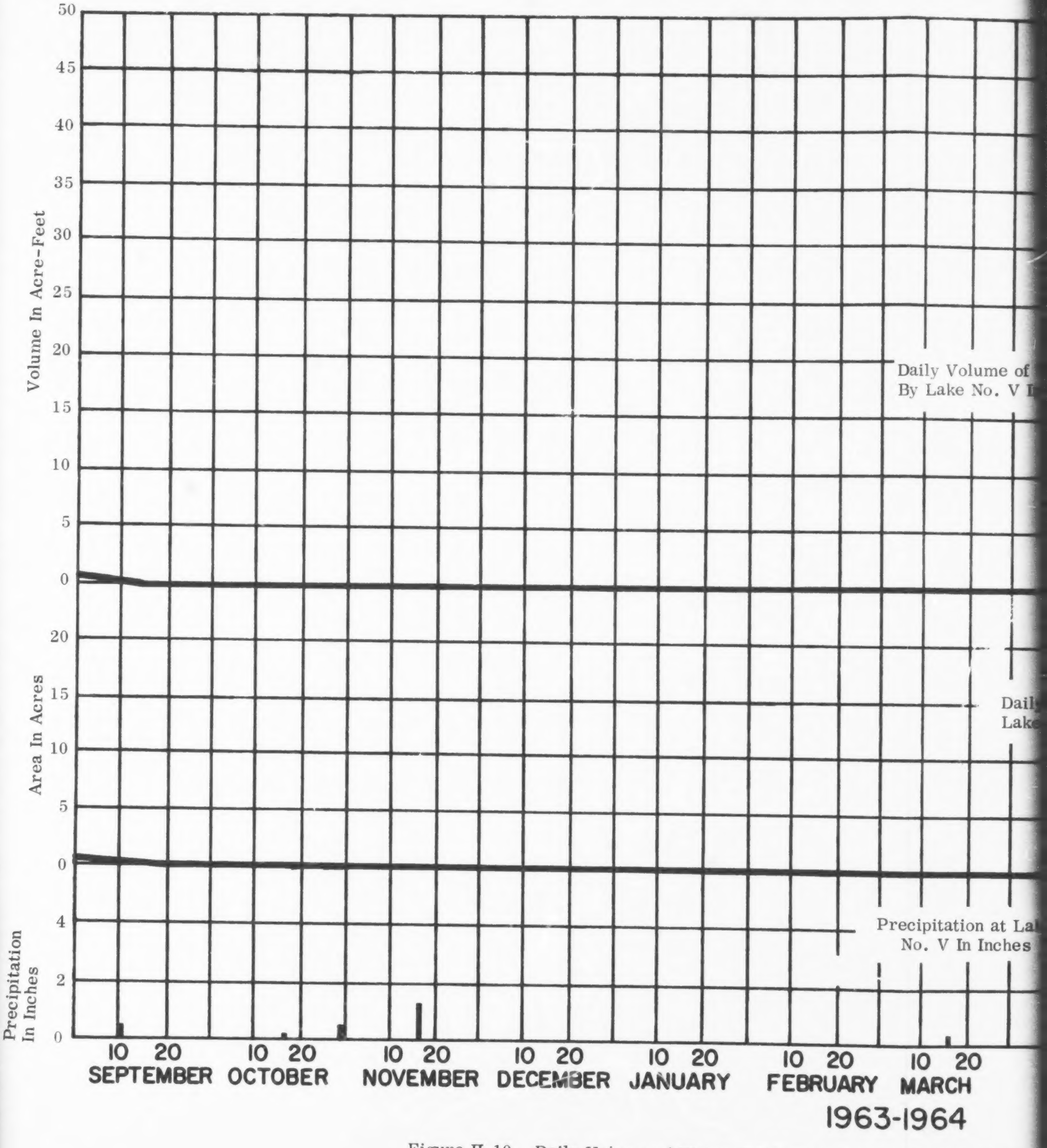
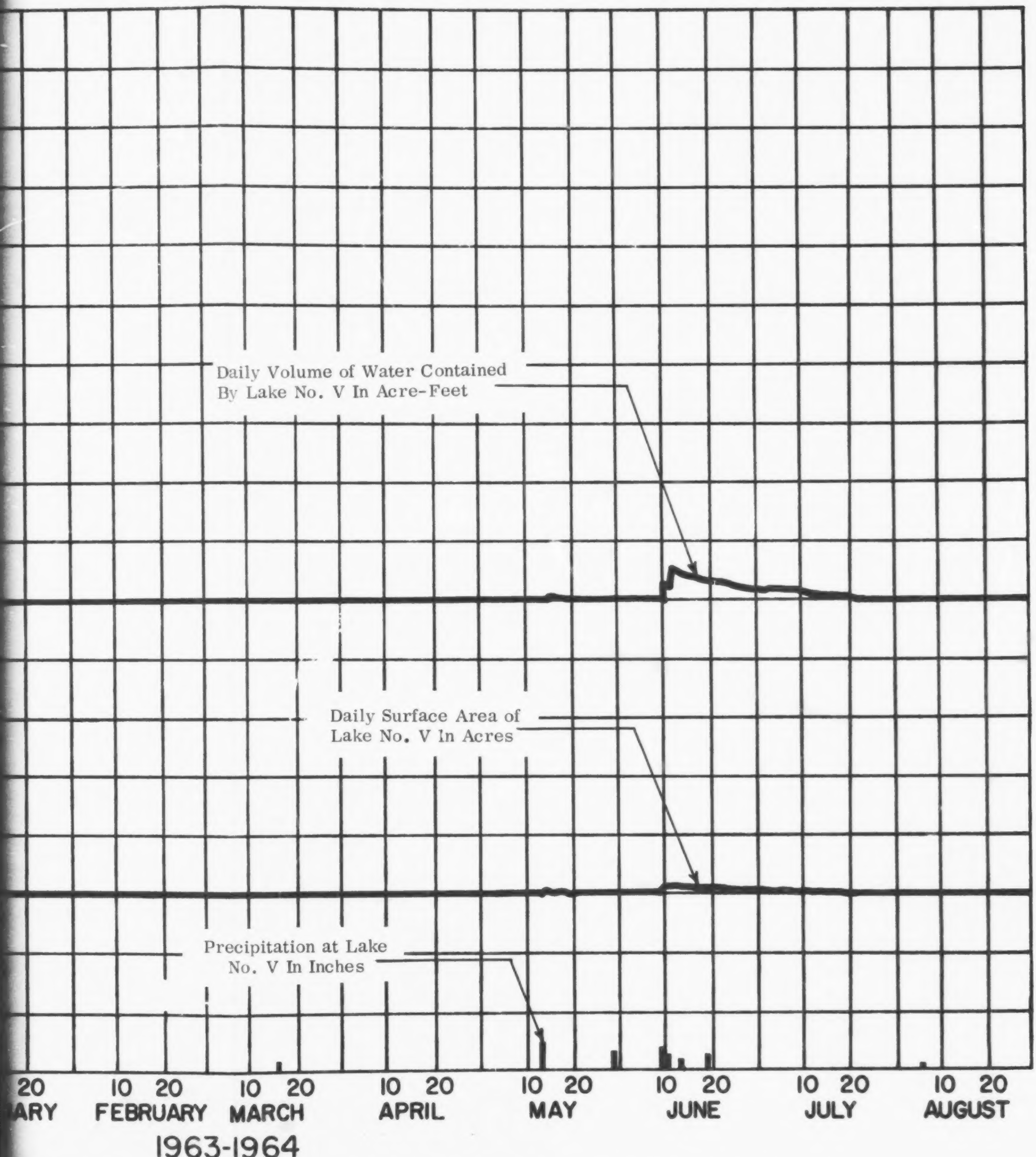


Figure II-10. Daily Volume of Water Contained By Lake, Daily Surface



Water Contained By Lake, Daily Surface Area of Lake and Precipitation at Lake No. V (Kitten).

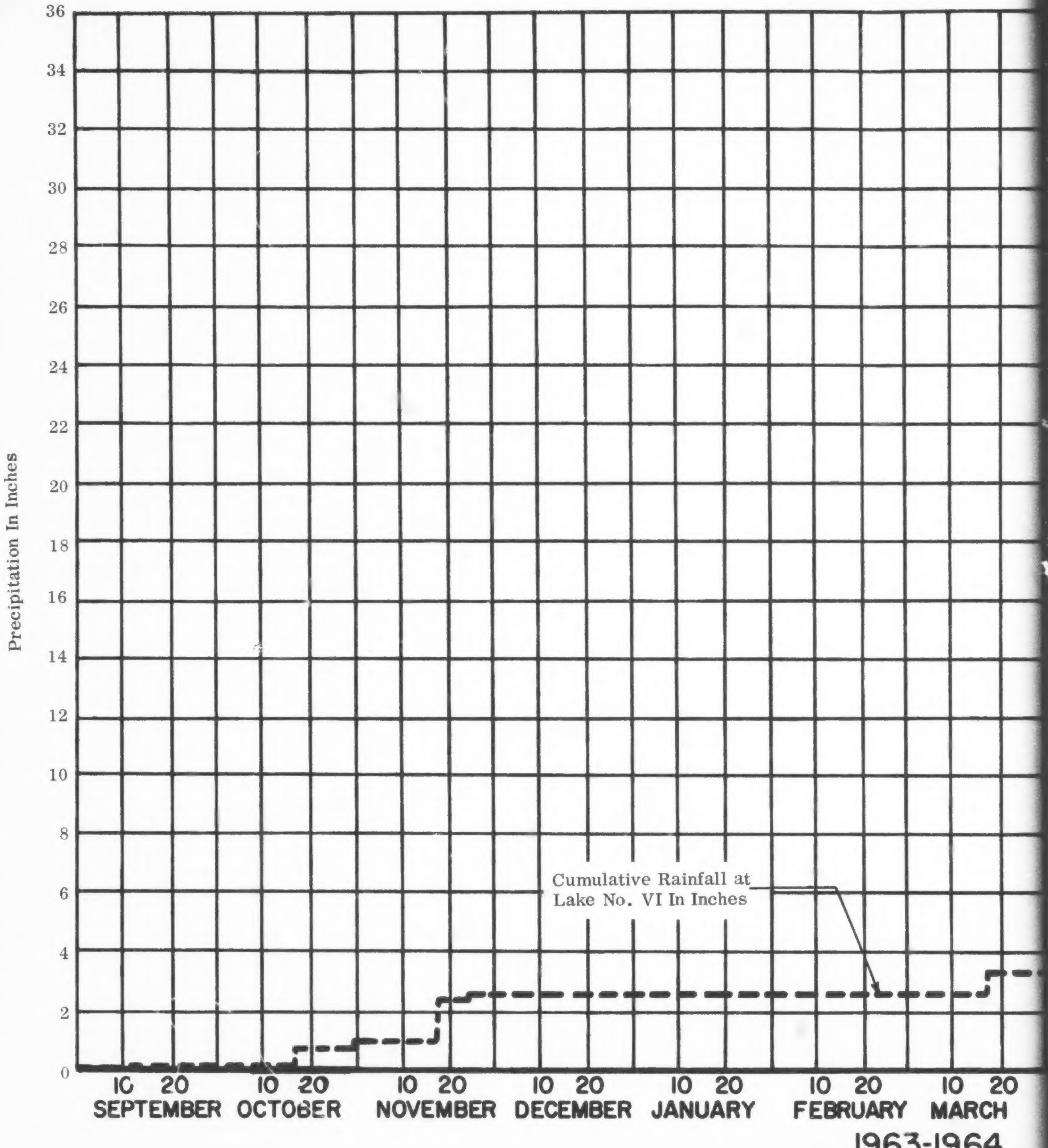
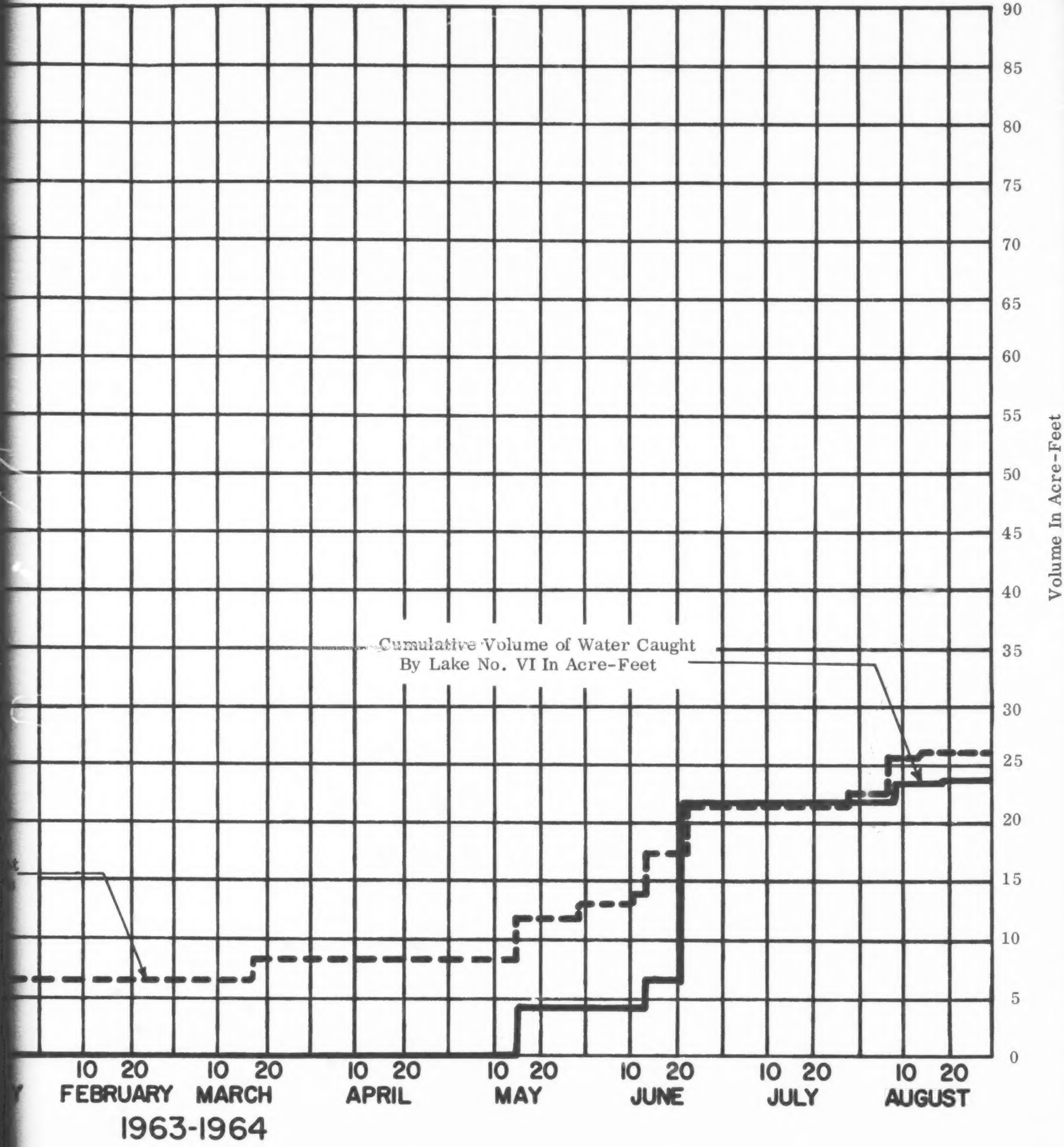


Figure II-11. Cumulative Rainfall and Cumulative Volume of



ainfall and Cumulative Volume of Water Caught By Lake No. VI (Holland).

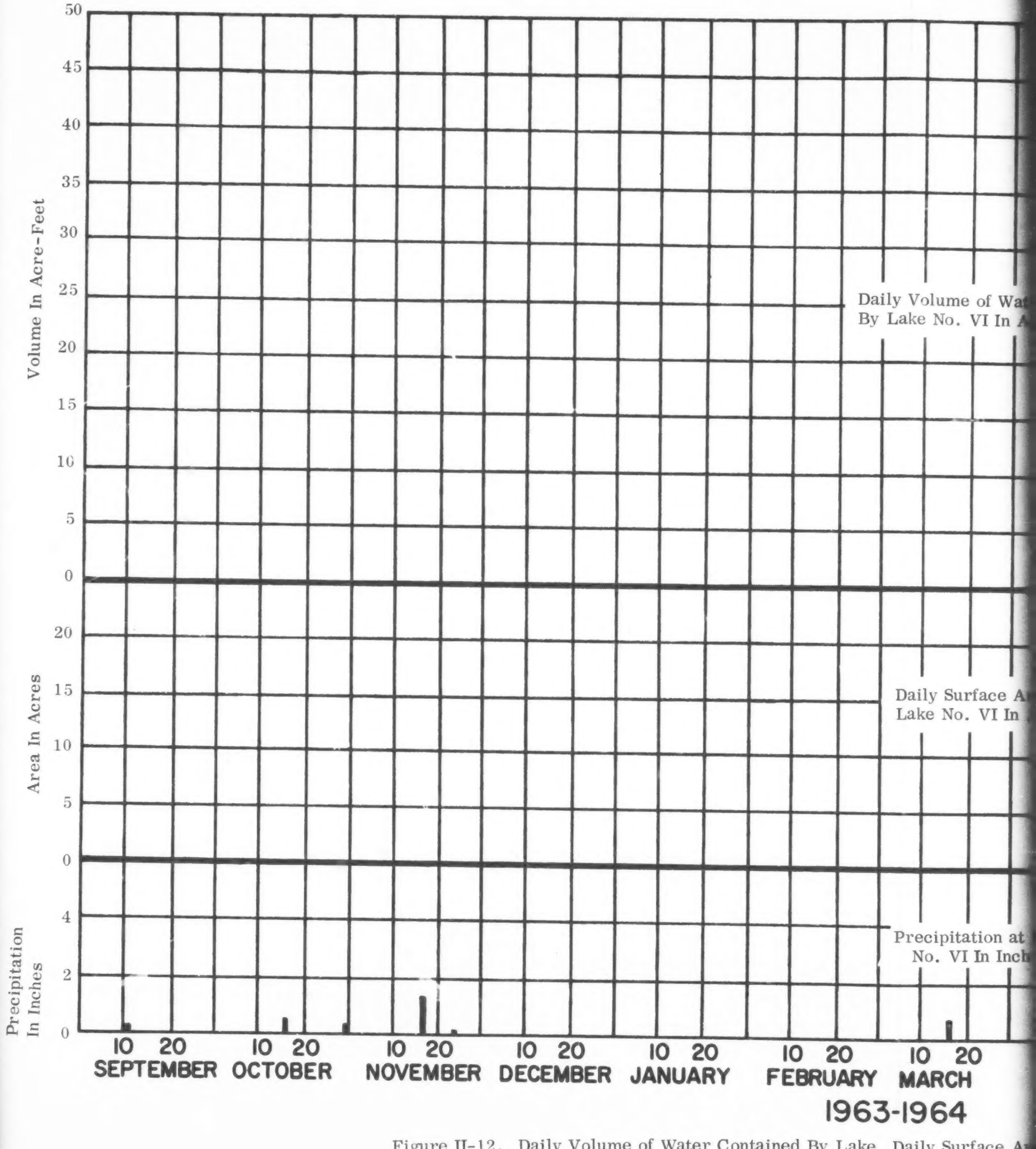
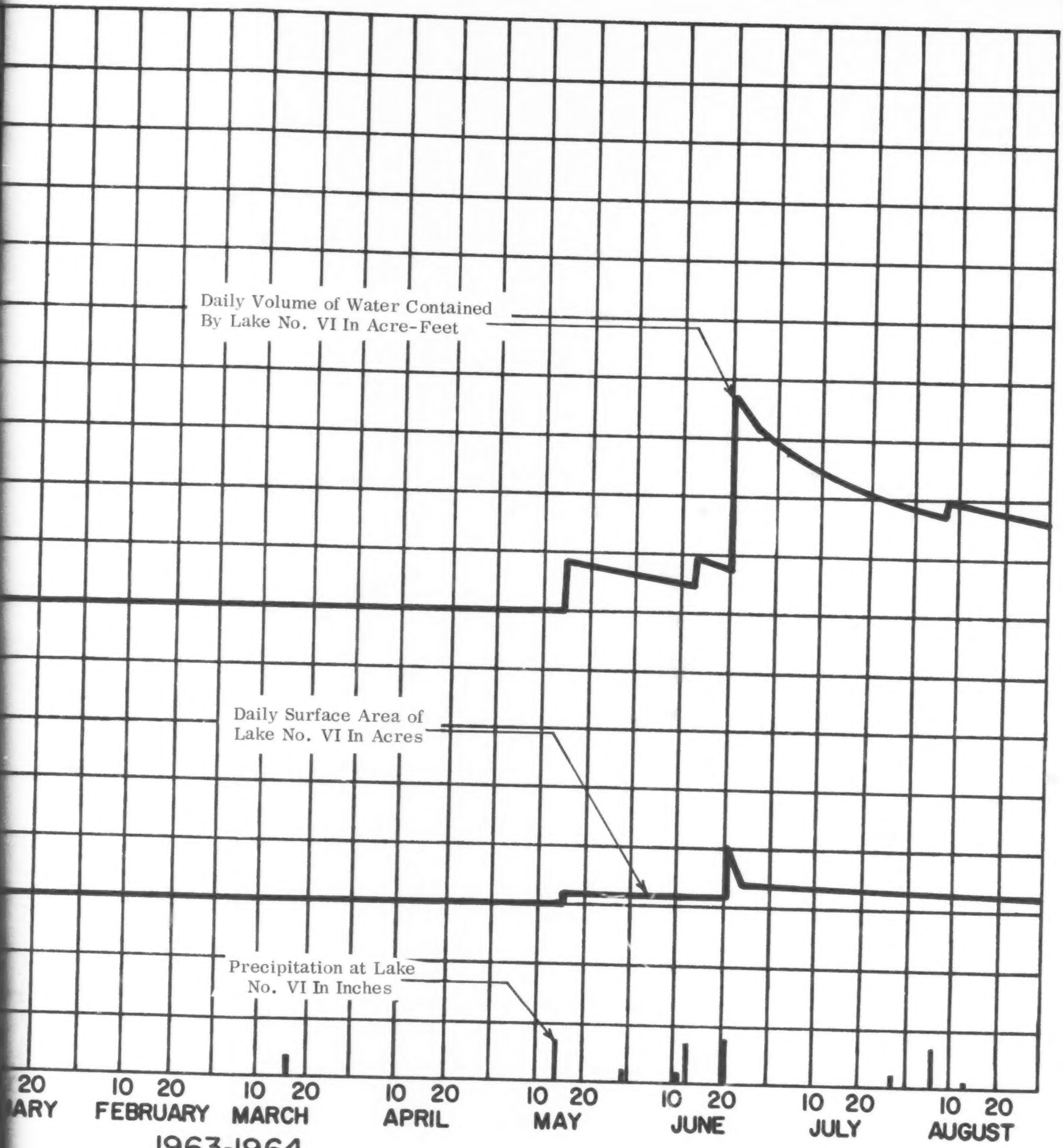


Figure II-12. Daily Volume of Water Contained By Lake, Daily Surface A



ter Contained By Lake, Daily Surface Area of Lake and Precipitation at Lake No. VI (Holland).

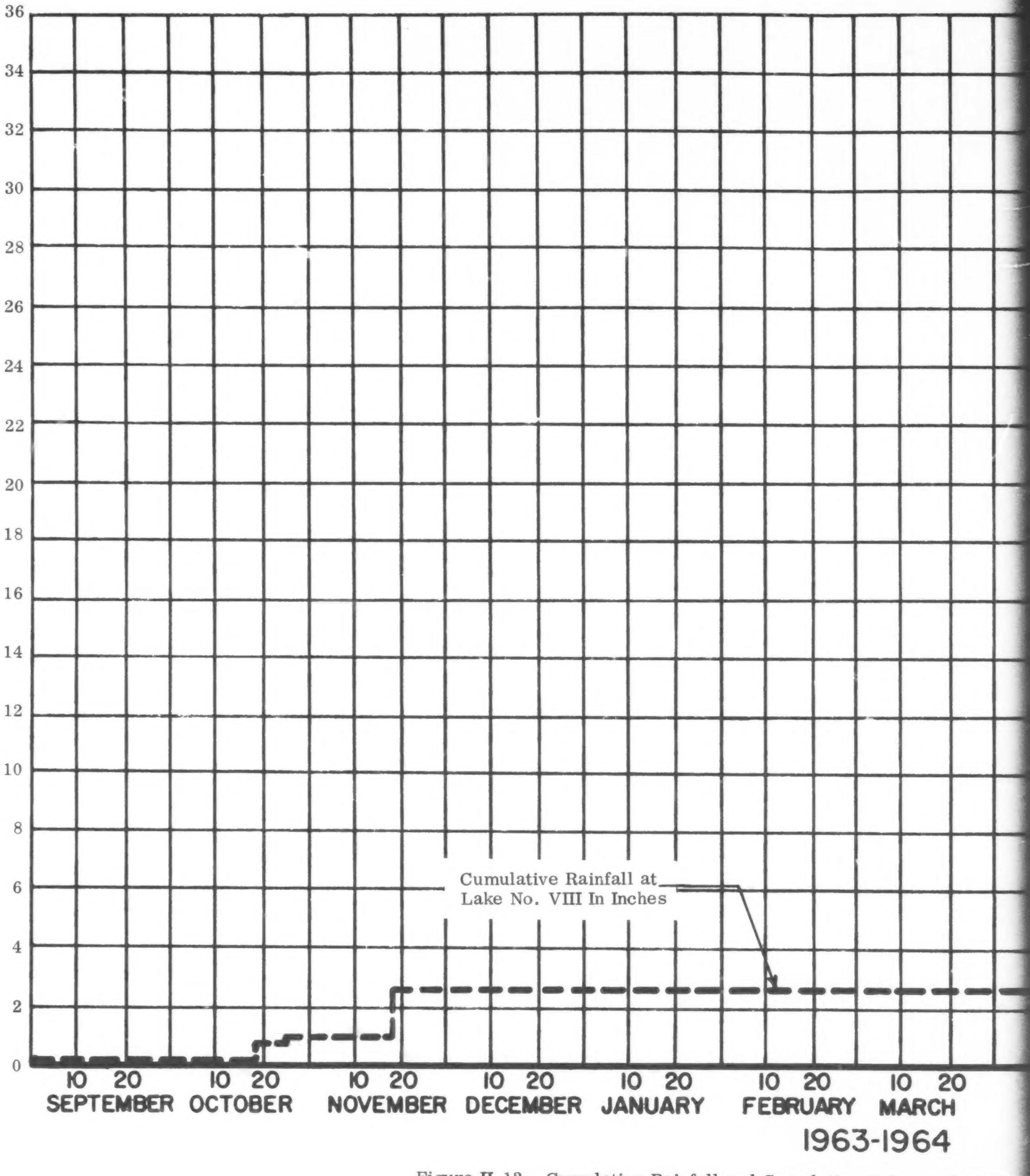
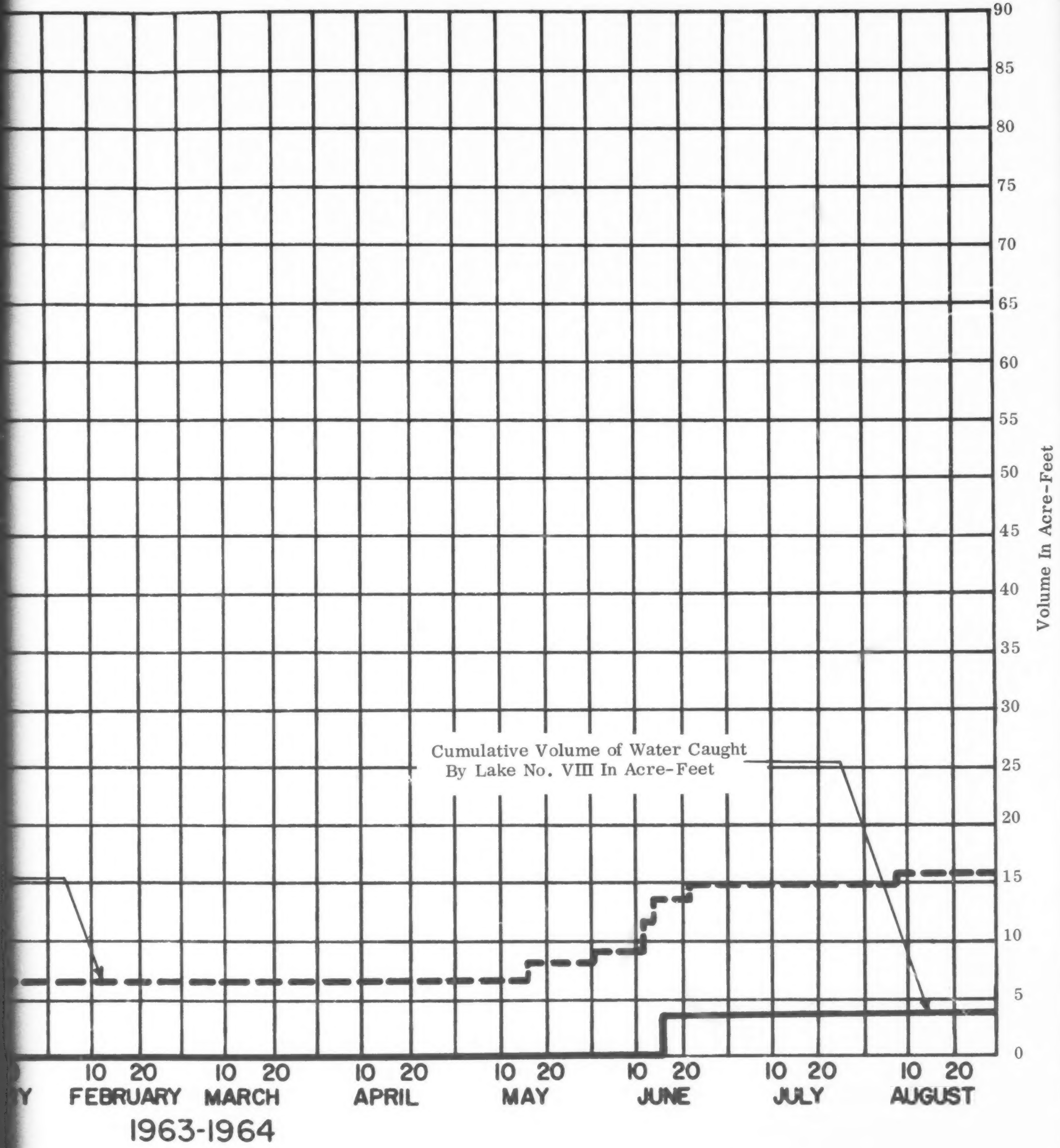


Figure II-13. Cumulative Rainfall and Cumulative Volume of Water



fall and Cumulative Volume of Water Caught By Lake No. VIII (Burgett).

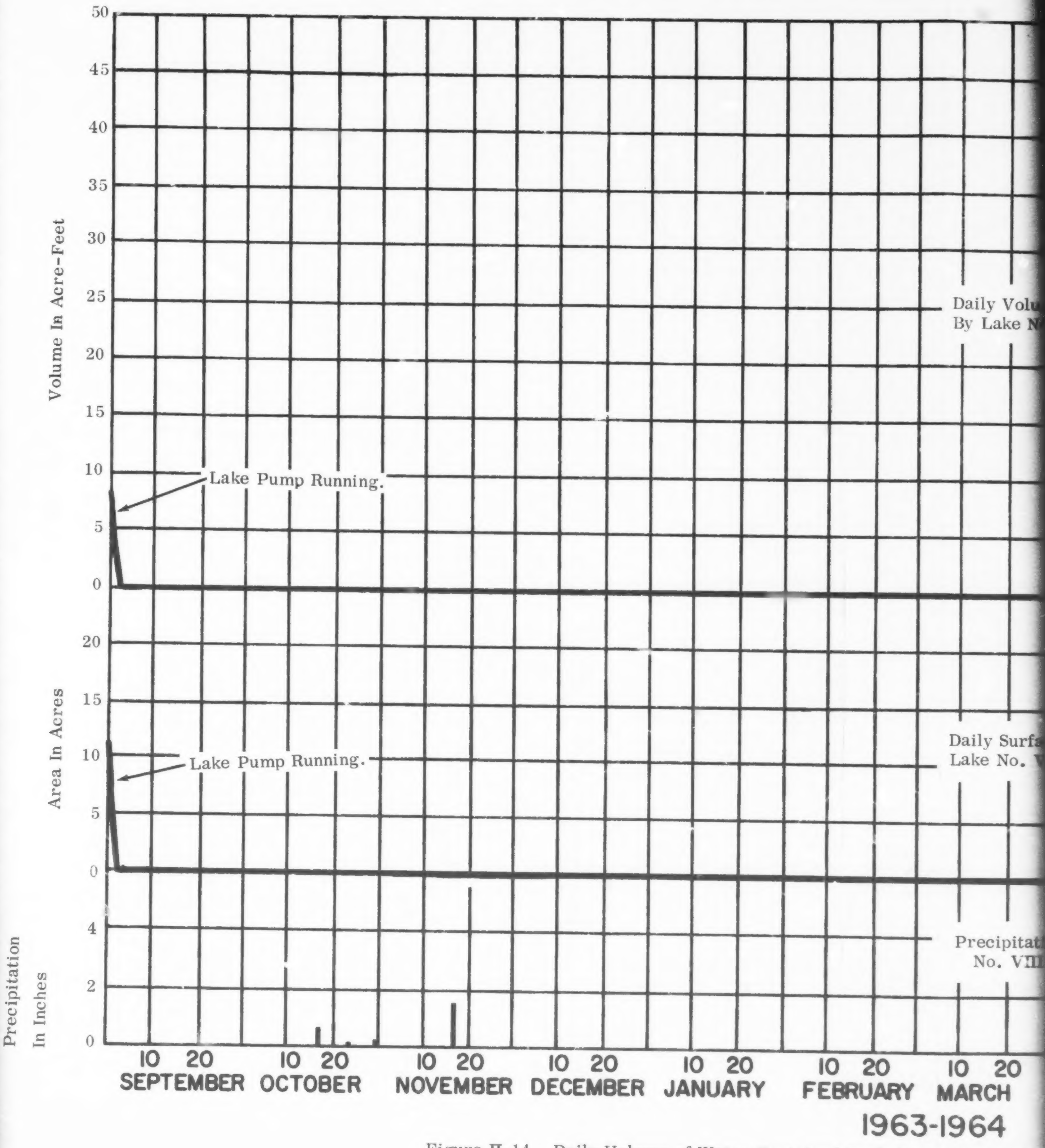
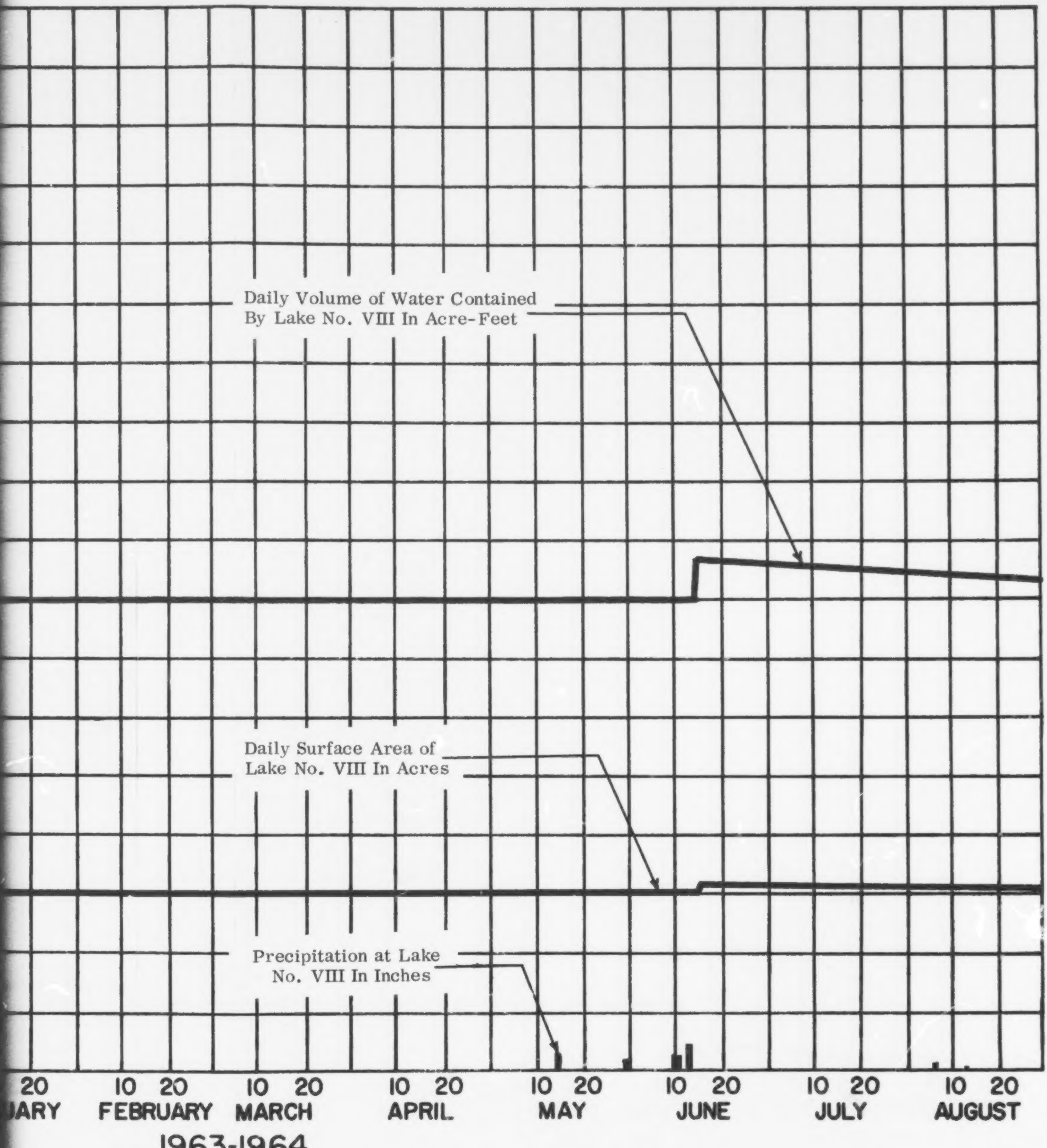


Figure II-14. Daily Volume of Water Contained By Lake, Daily Surface



ater Contained By Lake, Daily Surface Area of Lake and Precipitation at Lake No. VIII (Burgett).

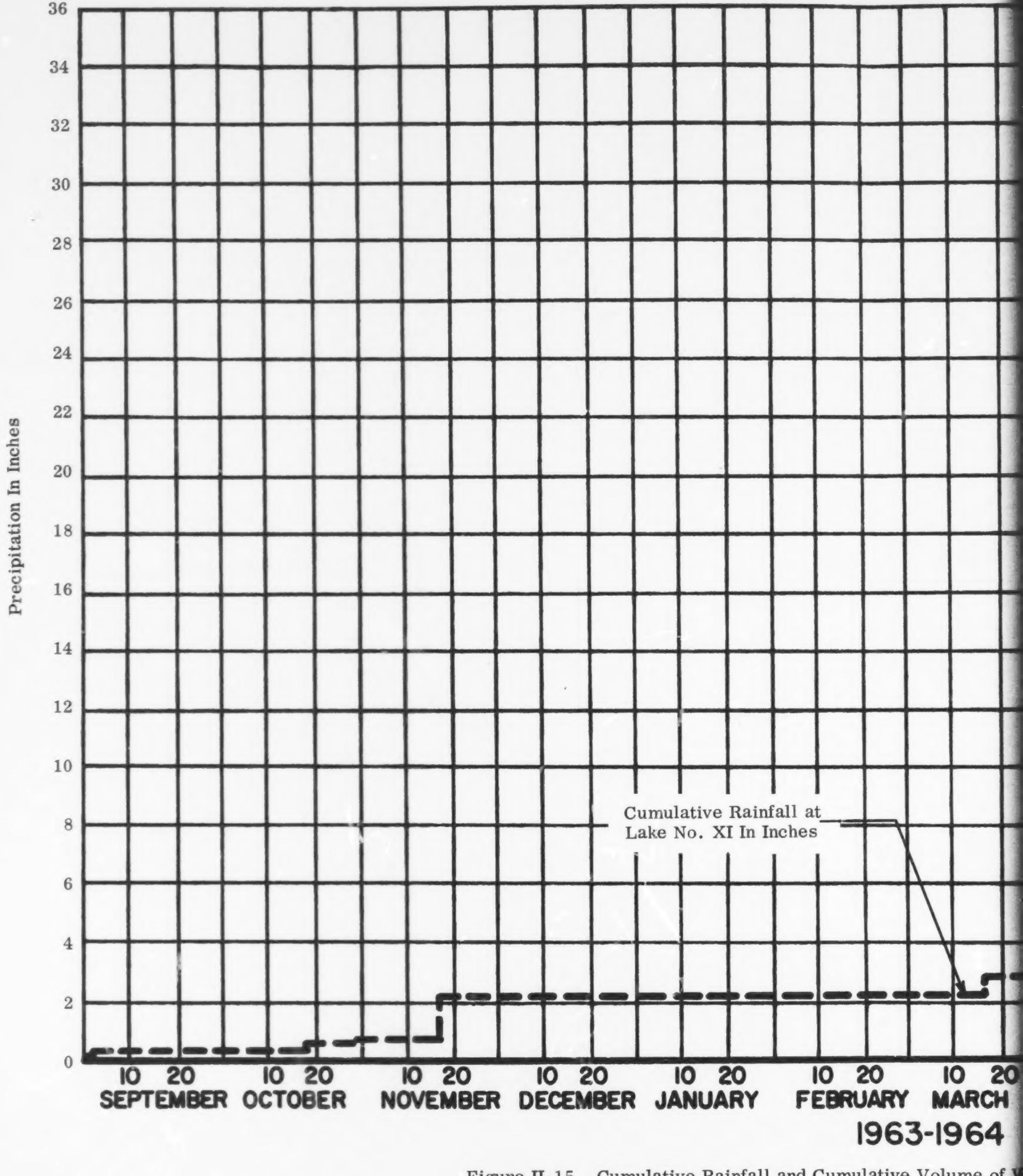
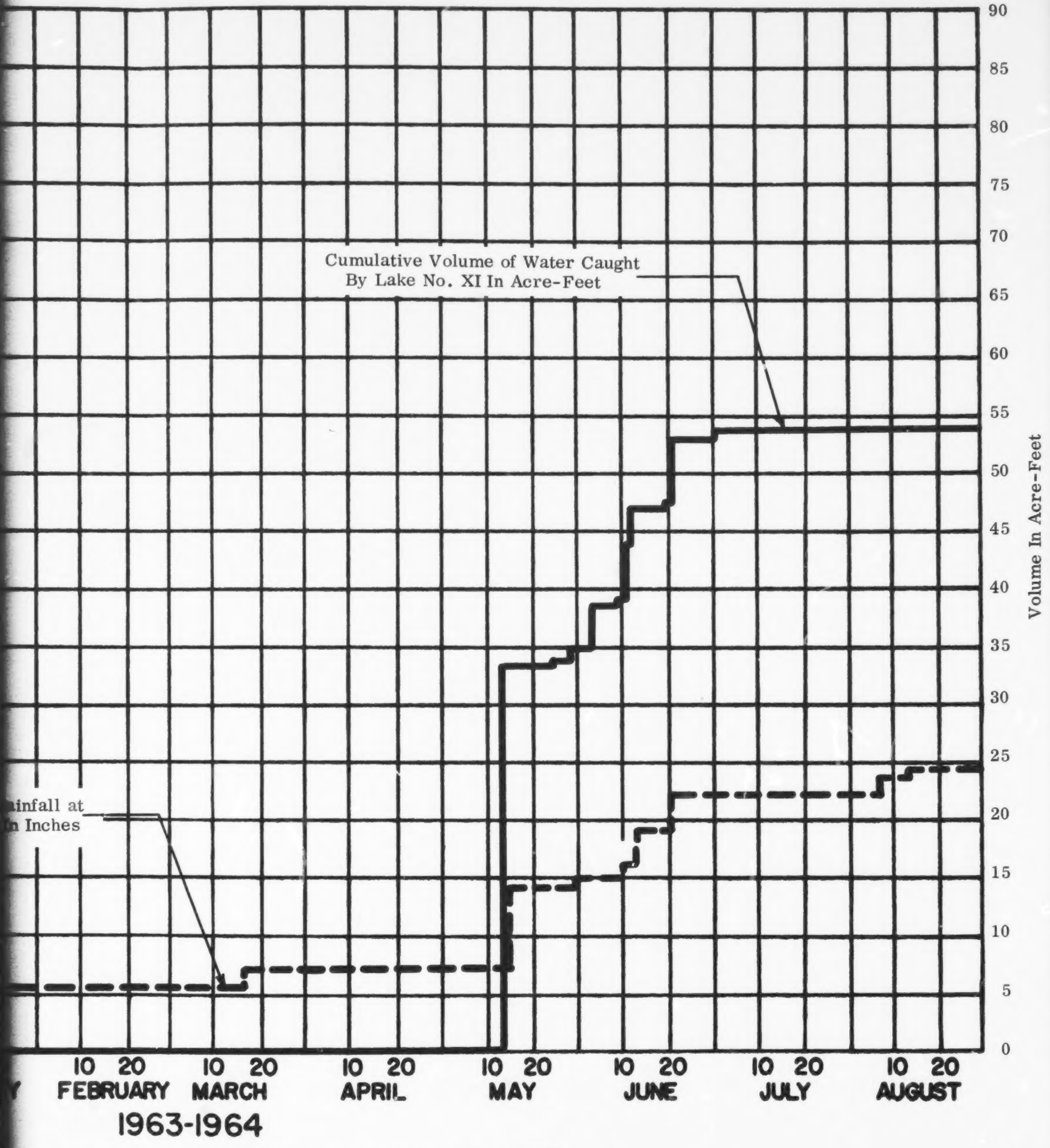


Figure II-15. Cumulative Rainfall and Cumulative Volume of W



ll and Cumulative Volume of Water Caught By Lake No. XI (Krueger).

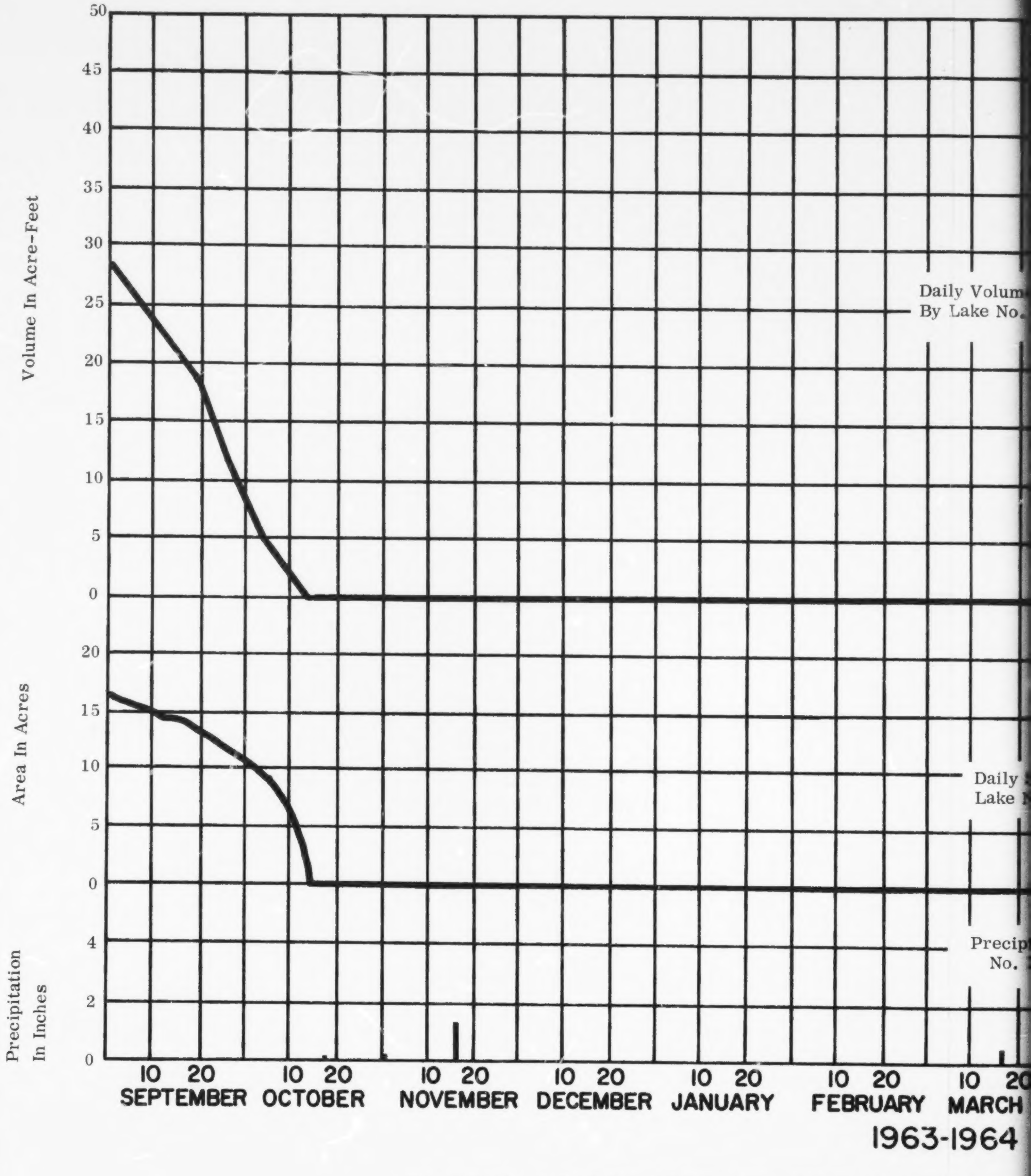
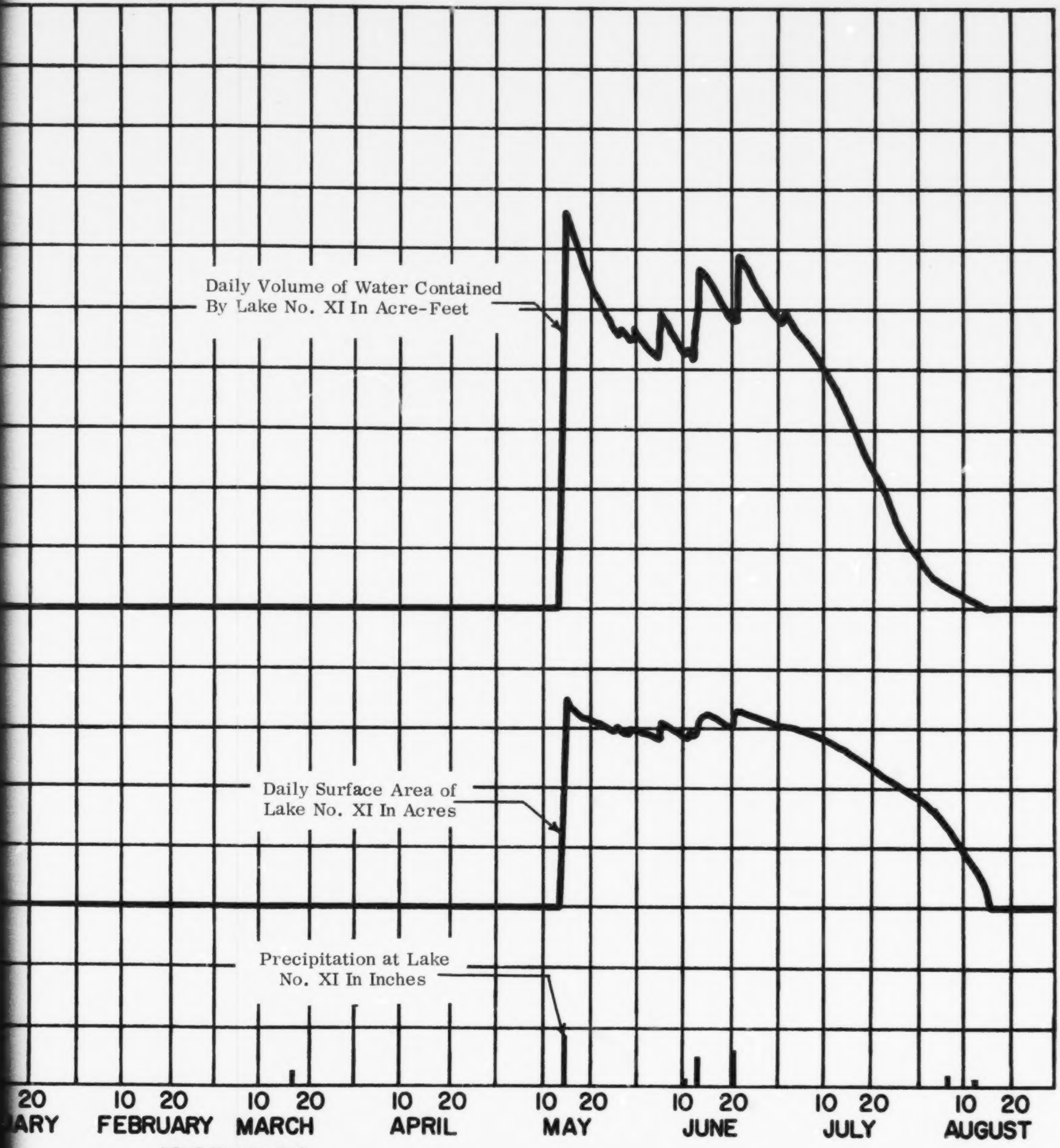


Figure II-16. Daily Volume of Water Contained By Lake, Daily Surfac



Contained By Lake, Daily Surface Area of Lake and Precipitation at Lake No. XI (Krueger).

APPENDIX III.

Mosquito Larvae Production Graphs and Mosquito Data Chart, Weekly Net Plankton and Vegetative Observations

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Table 1. The total number of larvae dipped during weekly sampling periods on each lake and the percent that was *Culex tarsalis*. Summers of 1962, 1963 and 1964. Lubbock County, Texas.

Date	I 1964	II 1962-63-64	III 1962-63-64	IV 1962-63-64	V 1962-63-64	VI 1962-63-64	VIII 1962-63-64	IX 1962-63-64	X 1962-63-64	XI 1963-64	XII 1964
3/31-4/6	Total No. % *C. t.*	d 3 -	d 0 0	d d	d 317 d -	d d d	d d d	d 29 d 0	64 d -		
4/7-13		- -	 0	d	1237 d 0 "	d "		217 " 0 "	d d		
4/14-20		- -	0 0	" "	d " "	d " "	d "	d " "	" "		
4/21-27		- -	0 0	" "	d " "	" "	" "	" "	" "		
4/28-5/4		- -	0 0	" "	d " "	" "	d " "	"	" "		
5/5-11		- -	0 0	" "	d " "	" "	1 " - "	"	" "		
5/12-18		- -	0 0	" "	d " "	d "	- " - "	d "	" d "		
5/19-25		- -	0 0	"	51 " - "	1 " - "	1 " -	4 -	" 4		
5/26-6/1		298 0	0 0	"	70 0 "	10 0	0 " 0 "	458 " 0	0 " 0		
6/2-8		1 0	0 0	 0	5 d - "	0 " 0	d 0 0	73 -	0 " 0		4
6/9-15		- 0 -	0	0 0	0 0 0	0 0 0 0	0 0 0	42 " 100 "	0 " 0	3	1
6/16-22		- -	0 0	0 0	1 0 100 0	0 0 0 0	0 0	29 - "	0 " 0	0	0
6/23-29	2 100%	- -	0 0	0 0	6 0 100 0	0 0 0 0	 0	2 100	0 0		
6/30-7/6		-	0 0	0 0	23 0 100 0	0 0 0 0	0 0	39 - "	44 " 100	1 100	28 100
7/7-13		- -	0 0	0 0	55 0 - 0	0 0 0 0	0 0	16 100 "	86 " 100	0 -	0 -
7/14-20		11 100	d 0	d 0 0	261 0 - 0	d 0 0 3 0 0	0 0	38 -	d 227 " -	7 100	16 100
7/21-27		d 1 d - -	40 0 - 0	37 0 - 0	d 6 0 100 0	- 0 0 0 d 0	0 0	142 " 100 "	64 84 " 100 100	58 100	d -
7/28-8/3		253 12 d 0 -	281 0 100	697 0 95 0	137 265 d 75 0 "	0 0 0 d 0	0	110 " 100 "	220 0 " 11 0	0 0	"
8/3-10		511 " 88	173 0 100	607 0 93	786 0 " 68 0 "	0 0 0 d 0	d d 0	d d "	126 0 " - 0	86 100	" "
8/11-17		29 - d 100 -	217 0 100 0	456 0 97	814 0 d 85 0 d	d d 0 0	d d 0 0	d d d "	134 d d 75	d	d "
8/18-24		229 24 100 0 "	d 0 0	496 0 100 0	565 194 " 30 - "	0 0	40 0 - 0	"	106 " -	"	"
8/25-31		79 156 100 -	0 0	25 - 0	187 70 " - 0 "	d 0 0	0 0 0 d 0	d "	d "	"	"
9/1-7		7 83 " 0 100	155 0 -	340 0 -	577 178 " 7 - "	14 0 - 0	0 0 0 0 0 0	177 d " 100 "	831 " 29 "	" "	" "
9/8-14		268 77 0 - "	19 0 - 0	- 0 0	235 0 " 45 0 "	68 d 0 - 0	42 0 0 0 0 0	- " "	85 " 46 "	" "	" "
9/15-21		127 8 100 -	- 0 -	24 - 0	94 0 " 80 0 "	1 0 0 0	33 0 0 60 0 0	215 100	124 " - "	" "	" "
9/22-28		574 - " 100 -	- 0 - 0	0 -	69 d " - "	d 0 0	17 0 0 - 0 0	31 " 100	10 - 0	 "	 "
9/29-10/5		124 - 100 -	2 - 0	20 0 -	d " "	0	28 0 - 0 0	33 " -	258 0 - 0	" "	" "
10/6-12	19 0%	203 - " 89 -	d 0	16 0 30	"		34 0 0 71 0 0	d "	d d	216 0%	
10/13-19	d "	- - " - - "		0 0 0 0	2 " - "		27 0 86 0 0	 "	" "	708 30%	
10/20-26	"	19 - - - "		2 0 -	159 " - "		60 0 0 90 0 0	"	39 - "		" "
10/27-11/2	"	- - - - "		6 -	661 " - "		56 0 0 61 0 0	"	286 " - "		" "
11/3-9		109 - - -		87 -	437 " -		16 0 - 0	"	d "		"
11/10-16		d d		15 -	d		26 d 25				
11/17-23				6 -			4 -				
11/24-30				0 0			6 -				
12/1-7				d			d				
12/8-14							27 0				
12/15-21							0 0				
12/22-28											
12/29-31		d d	d	d	d d	d d	d d	d d	d d		

Note: "d" means "dry"

Table 2- Date of first inundation, date of first mosquito production, date lake first went dry, date of second inundation, and date lake went dry for the last time in the study period for each lake. 1962, 1963 and 1964 Seasons. Lubbock County, Texas

Lake	Date 1st Filled			Date 1st Prod.			Date Dry			Date Refilled			Date Dry		
	1962	1963	1964	1962	1963	1964	1962	1963	1964	1962	1963	1964	1962	1963	1964
I Huckabee		4/22	5/20		None	10/3		4/30	6/30		6/1	9/20		8/27	10/6
II Knowles	4/5	3/22	3/10	7/28	3/25	None	4/15	4/5	3/27	7/25	5/20	6/20	11/13	10/22	7/21
III Hufstedler	4/22	4/8		4/23	None	None	8/20			9/5			9/28		
IV L.C.C.	6/12	5/5	5/18	7/24	None	None	10/20	4/16	4/23	10/21	5/27	6/12	12/23		10/30
V Kitten	5/15	4/3	6/10	5/18	4/6	6/16	5/30	4/12	7/21	7/17	5/22	9/20	10/25	9/15	10/7
VI Holland	7/20	5/21	3/26	7/21	5/23	None	7/28	7/29		7/30		9/3	8/7		
VIII Burgett	6/14	5/7	5/20	6/16	5/10	None	7/5	10/4	9/13	7/20	-	-	12/28*		
IX Cox	4/6	3/29	9/13	4/10	4/1	None	4/18	8/5	9/16	9/5	-	-	10/12		
X Dupree	6/11	4/3	9/13	6/17	4/5	9/16	7/8	4/9	10/1	9/4	5/27	-	11/4	8/20	-
XI Krueger	no rec.	4/29	5/20	None	4/1	6/9	-	10/22	8/5	-	-	9/13			
XII Idalou Gambusia Pit	no rec.	no rec.	5/20	-	-	6/2	-	-	10/11	-	-	-	-	-	-

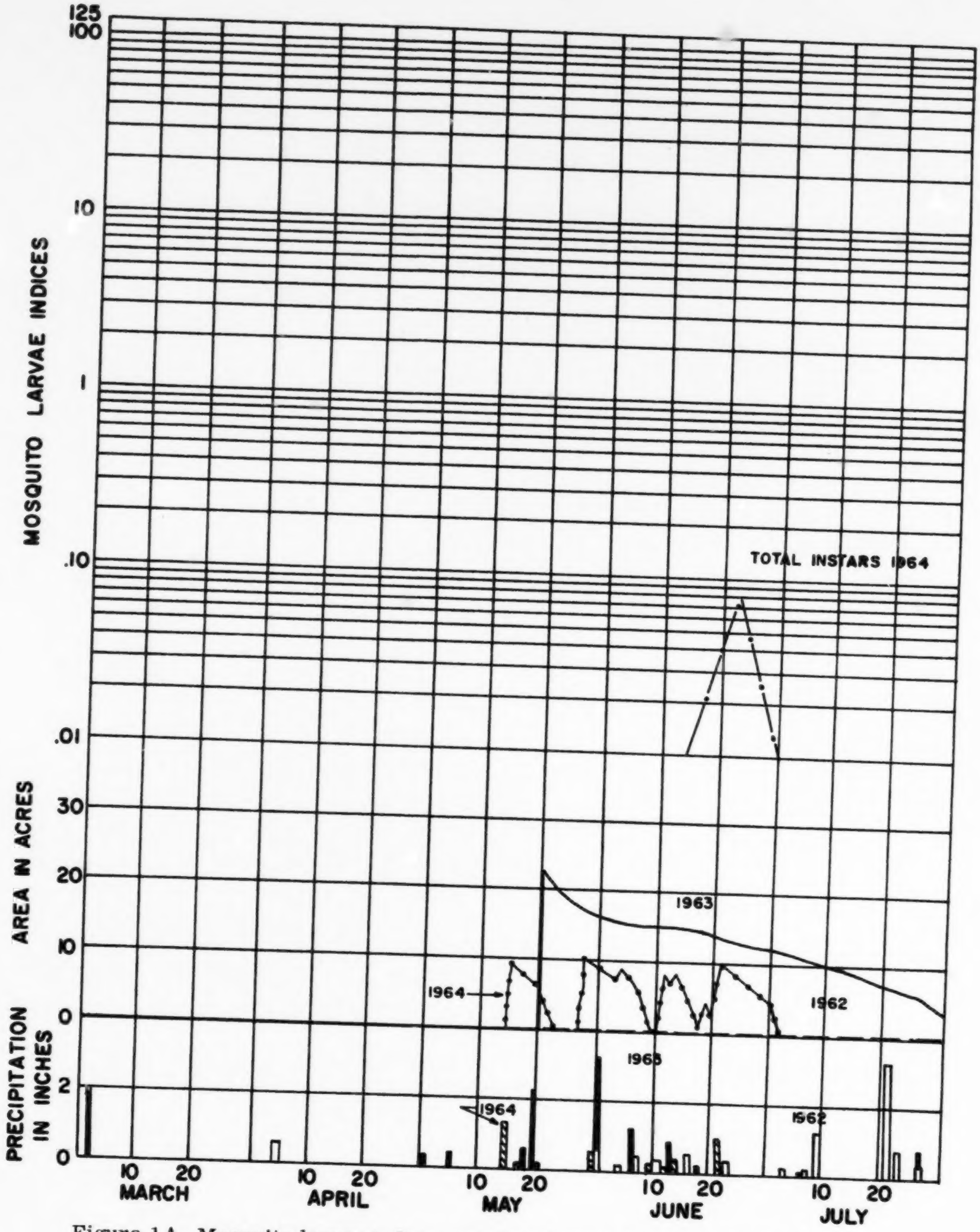

Figure 1A. Mosquito larvae indices presented semi-logarithmically for both fourth instar larvae and total of all instars taken twice weekly during the 1962 season and once weekly during the 1963 and 1964 seasons by sampling at thirty foot intervals on ten transects; in relation to daily surface acres and rainfall. Spring and summer 1962, 1963 and 1964. Lake I (Huckabee).

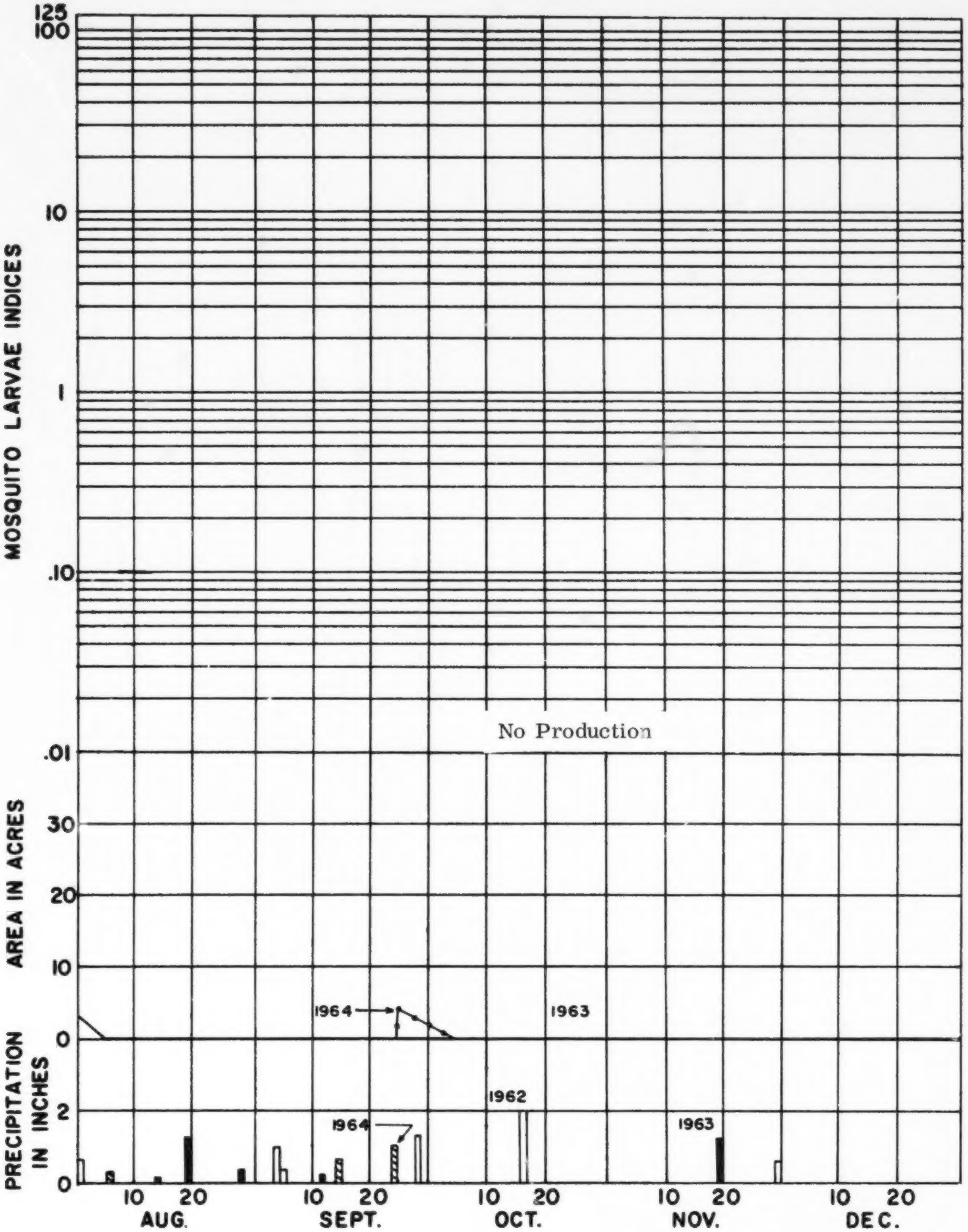

Figure 1B. Mosquito larvae indices presented semi-logarithmically for both fourth instar larvae and total of all instars taken twice weekly during the 1962 season and once weekly during the 1963 and 1964 seasons by sampling at thirty foot intervals on ten transects; in relation to daily surface acres and rainfall. Fall and winter 1962, 1963 and 1964. Lake I (Huckabee).

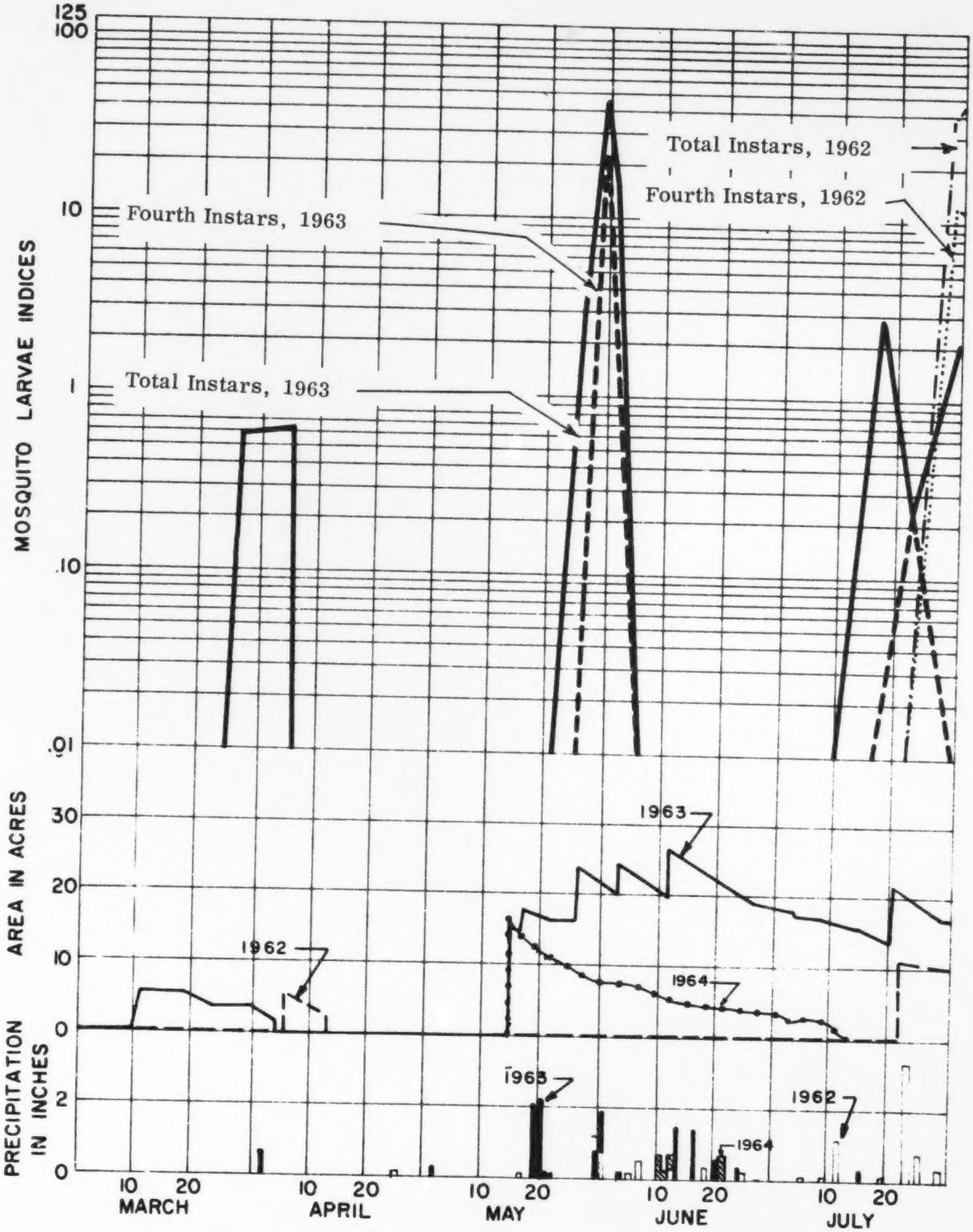

Figure 2A. Mosquito larvae indices presented semi-logarithmically for both fourth instar larvae and total of all instars taken twice weekly during the 1962 season and once weekly during the 1963 and 1964 seasons by sampling at thirty foot intervals on ten transects; in relation to daily surface acres and rainfall. Spring and summer 1962, 1963 and 1964. Lake II (Knowles).

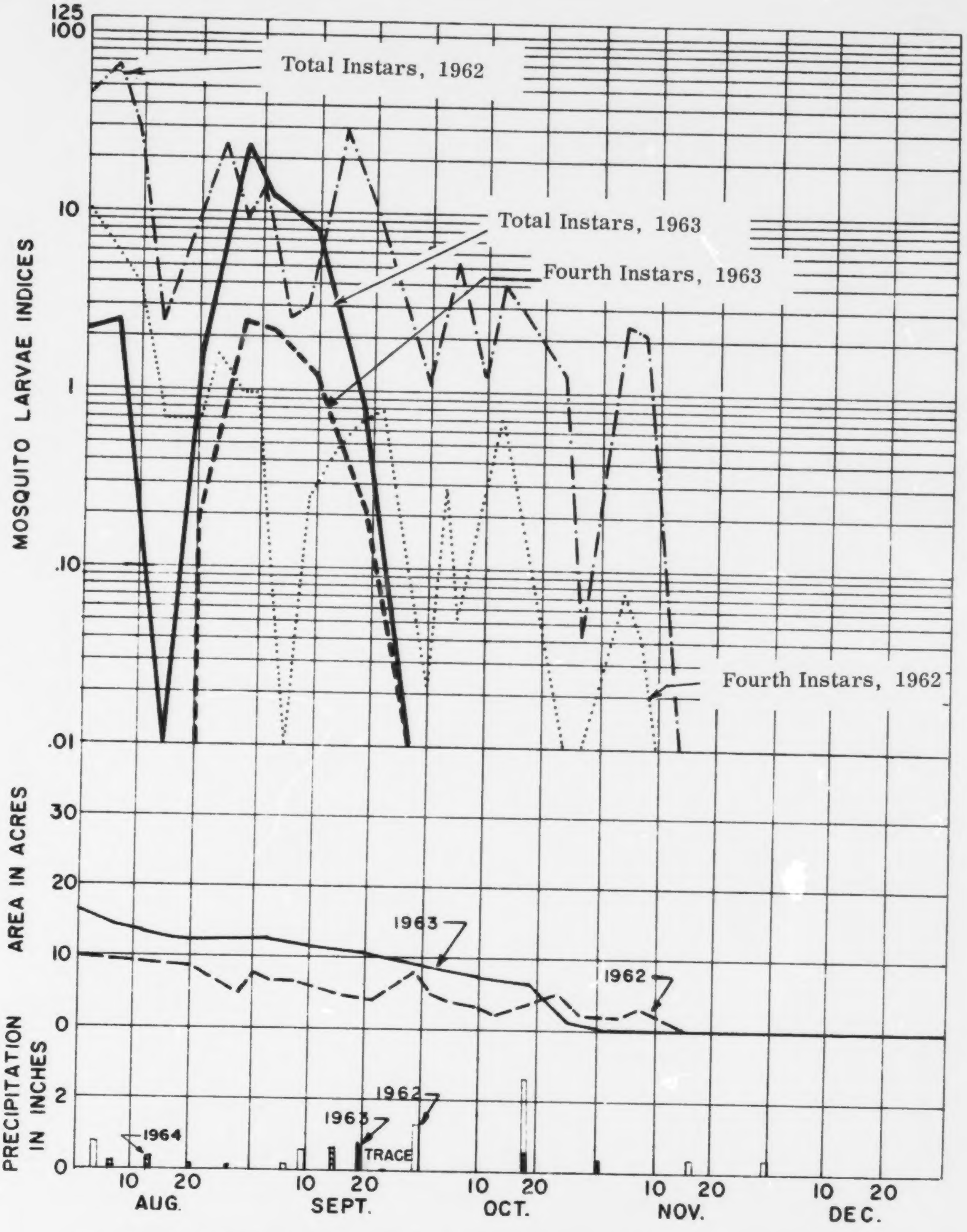

Figure 2B. Mosquito larvae indices presented semi-logarithmically for both fourth instar larvae and total of all instars taken twice weekly during the 1962 season and once weekly during the 1963 and 1964 seasons by sampling at thirty foot intervals on ten transects; in relation to daily surface acres and rainfall. Fall and winter 1962, 1963 and 1964. Lake II (Knowles).

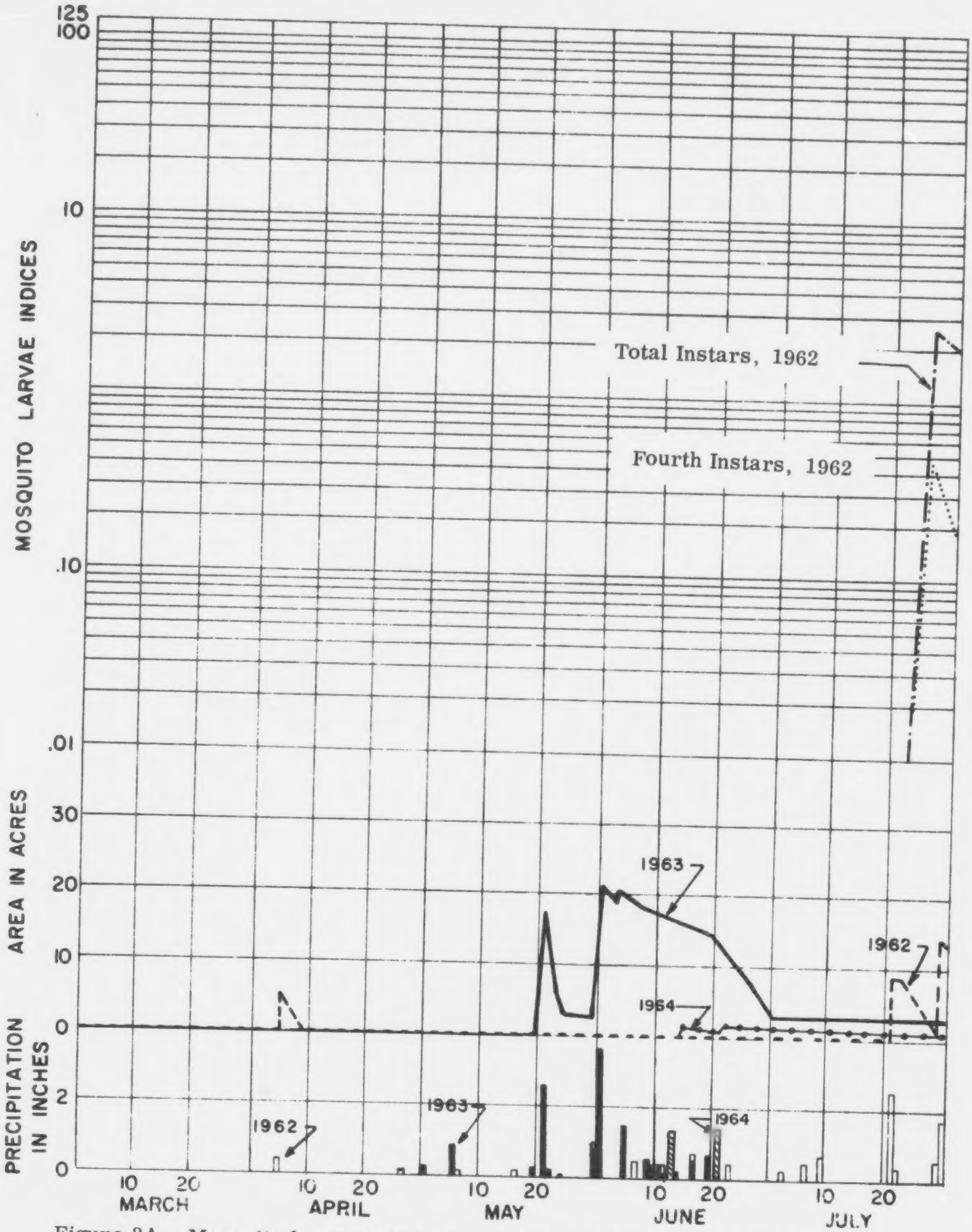

Figure 3A. Mosquito larvae indices presented semi-logarithmically for both fourth instar larvae and total of all instars taken twice weekly during the 1962 season and once weekly during the 1963 and 1964 seasons by sampling at thirty foot intervals on ten transects; in relation to daily surface acres and rainfall. Spring and summer 1962, 1963 and 1964. Lake III (Hufstedler).

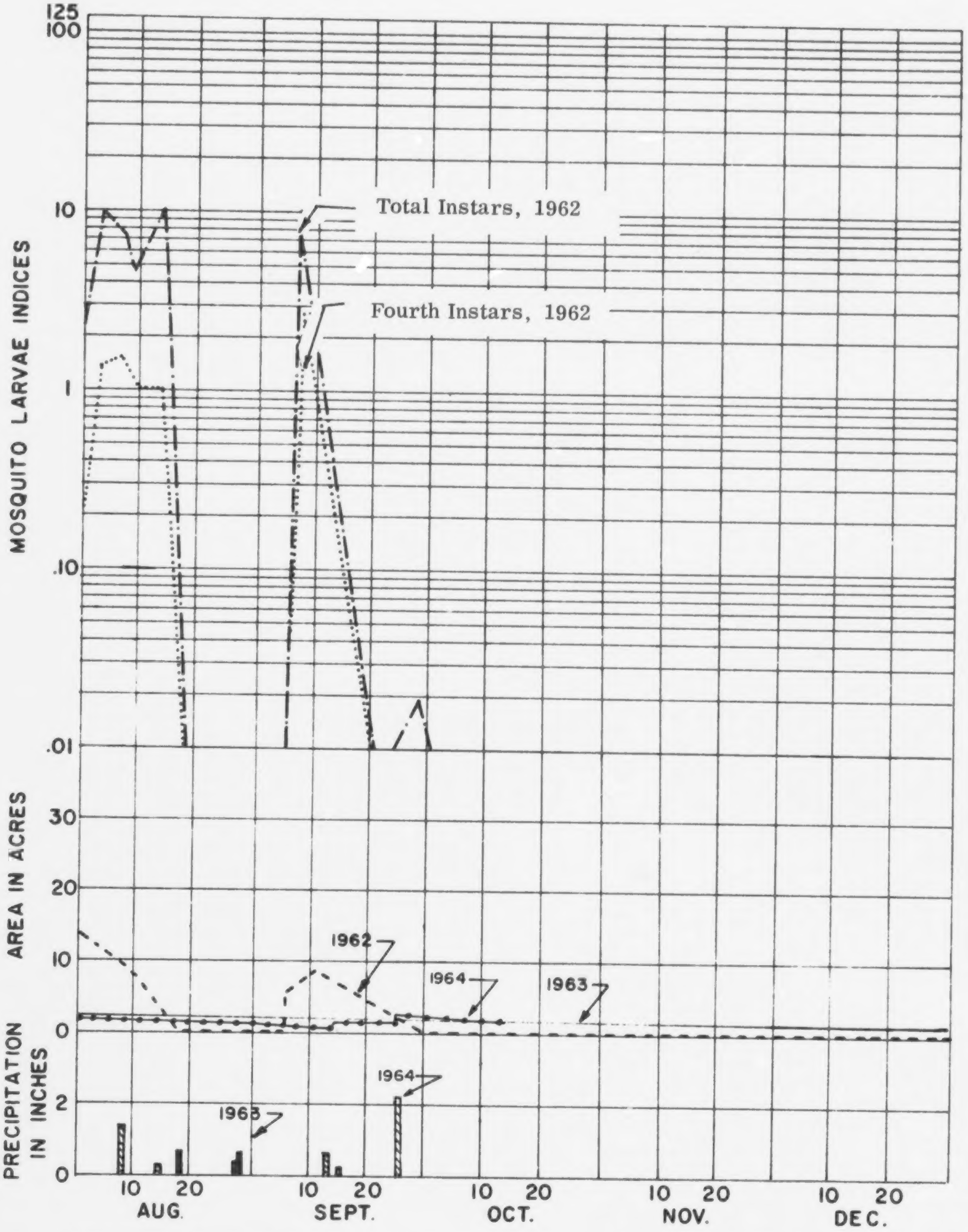

Figure 3B. Mosquito larvae indices presented semi-logarithmically for both fourth instar larvae and total of all instars taken twice weekly during the 1962 season and once weekly during the 1963 and 1964 seasons by sampling at thirty foot intervals on ten transects; in relation to daily surface acres and rainfall. Fall and winter 1962, 1963 and 1964. Lake III (Hufstedler).

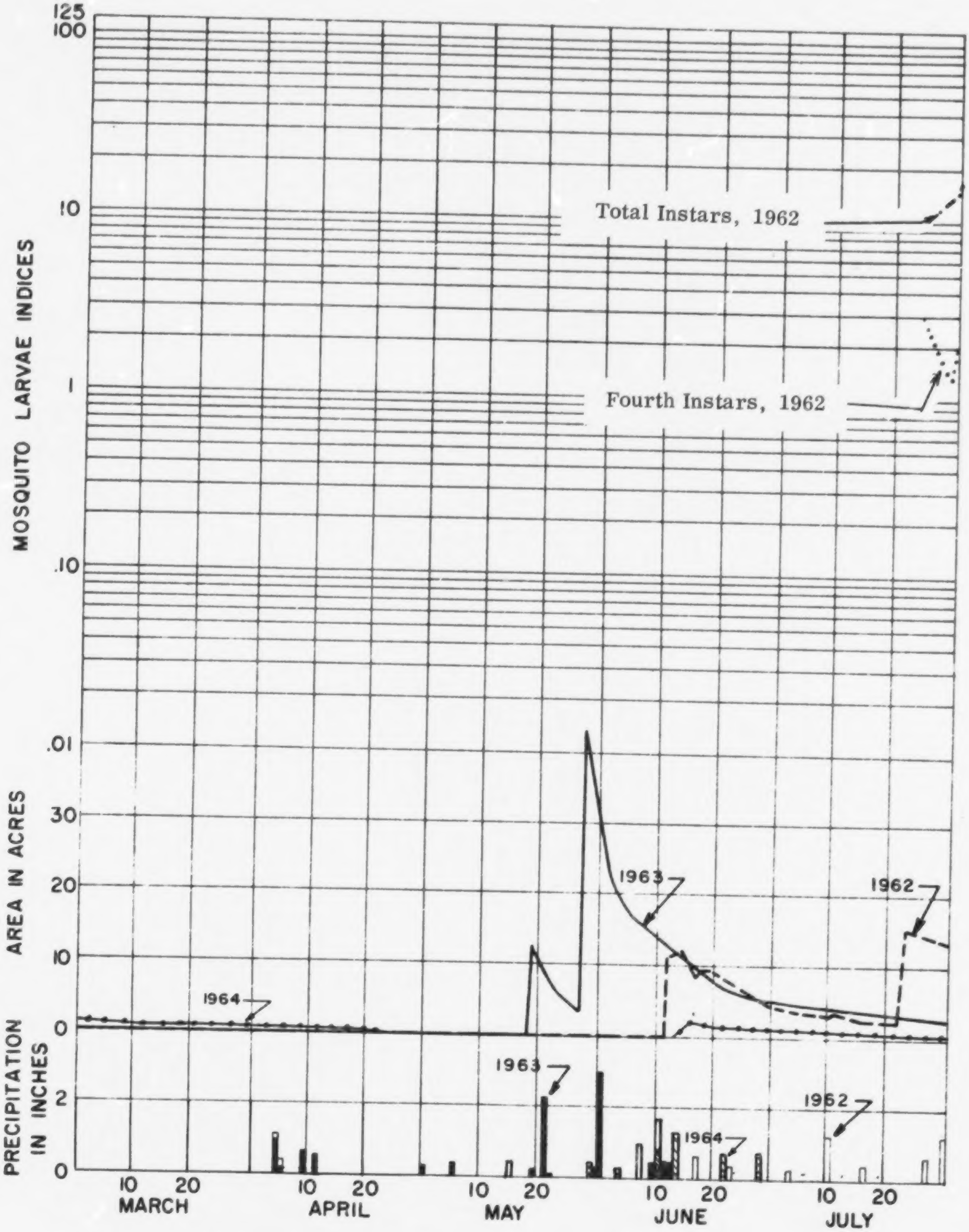

Figure 4A. Mosquito larvae indices presented semi-logarithmically for both fourth instar larvae and total of all instars taken twice weekly during the 1962 season and once weekly during the 1963 and 1964 seasons by sampling at thirty foot intervals on ten transects; in relation to daily surface acres and rainfall. Spring and summer 1962, 1963 and 1964. Lake IV (L.C.C.).

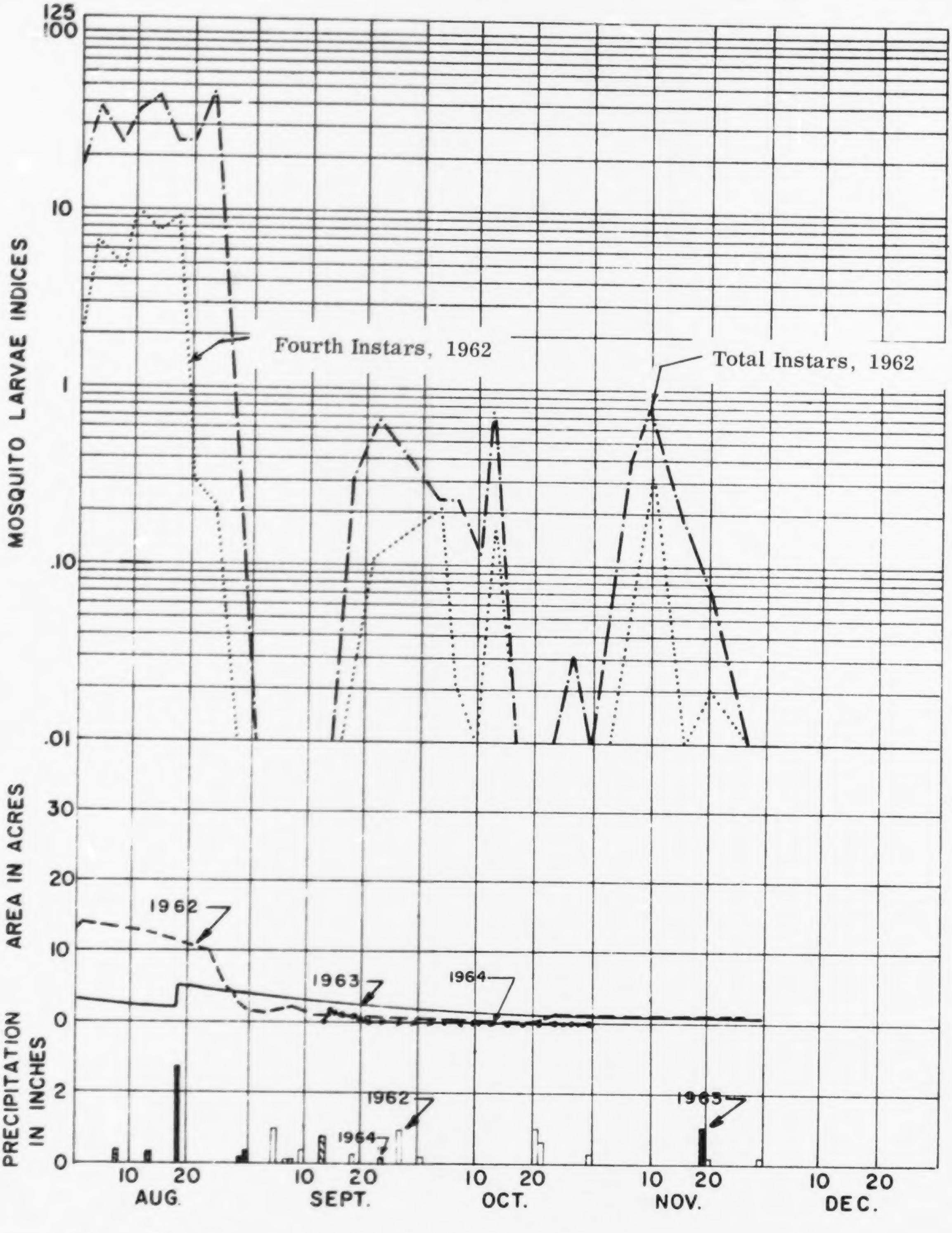

Figure 4B. Mosquito larvae indices presented semi-logarithmically for both fourth instar larvae and total of all instars taken twice weekly during the 1962 season and once weekly during the 1963 and 1964 seasons by sampling at thirty foot intervals on ten transects; in relation to daily surface acres and rainfall. Fall and winter 1962, 1963 and 1964. Lake IV (L.C.C.)

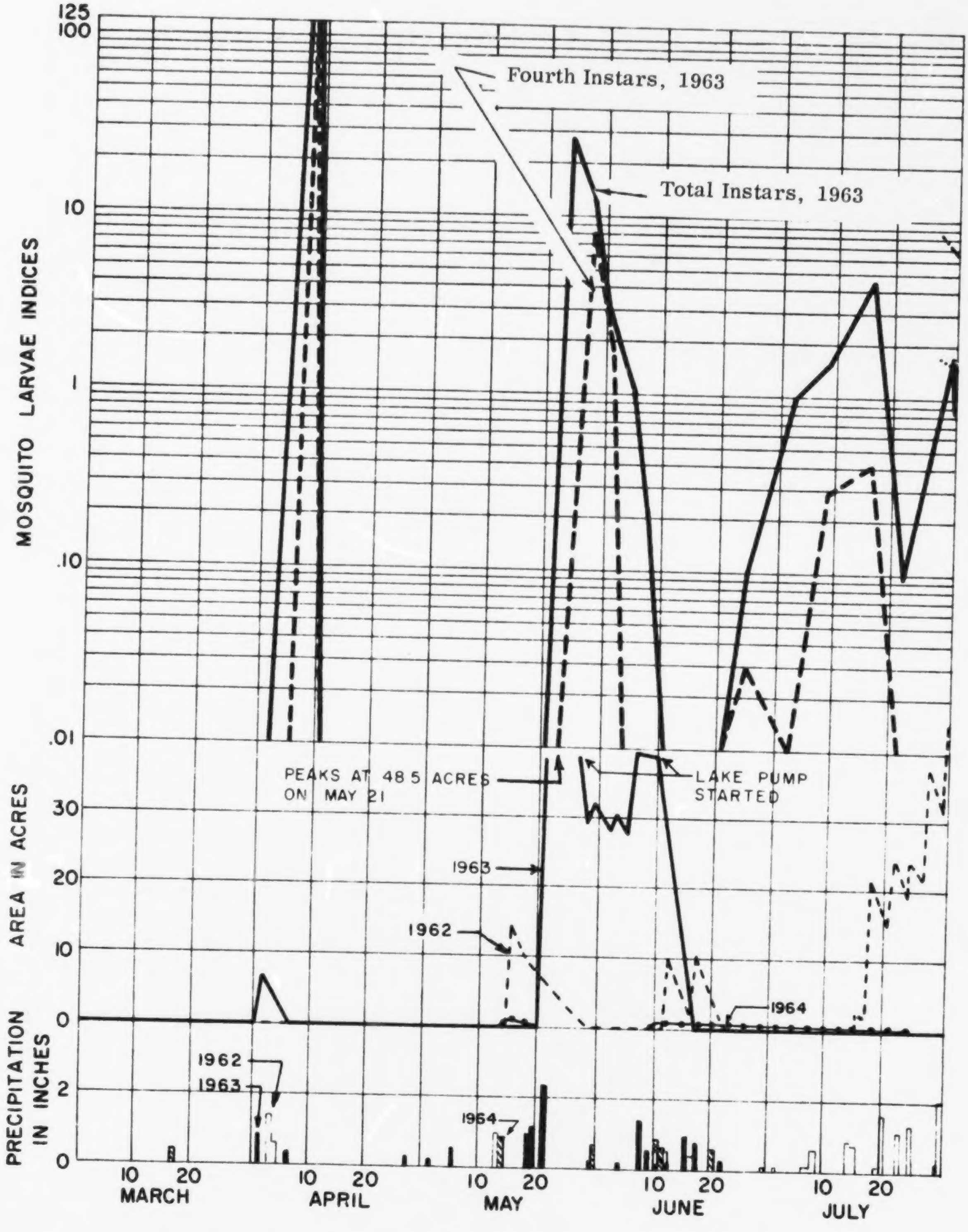

Figure 5A. Mosquito larvae indices presented semi-logarithmically for both fourth instar larvae and total of all instars taken twice weekly during the 1962 season and once weekly during the 1963 and 1964 seasons by sampling at thirty foot intervals on ten transects; in relation to daily surface acres and rainfall. Spring and summer 1962, 1963 and 1964. Lake V (Kitten).

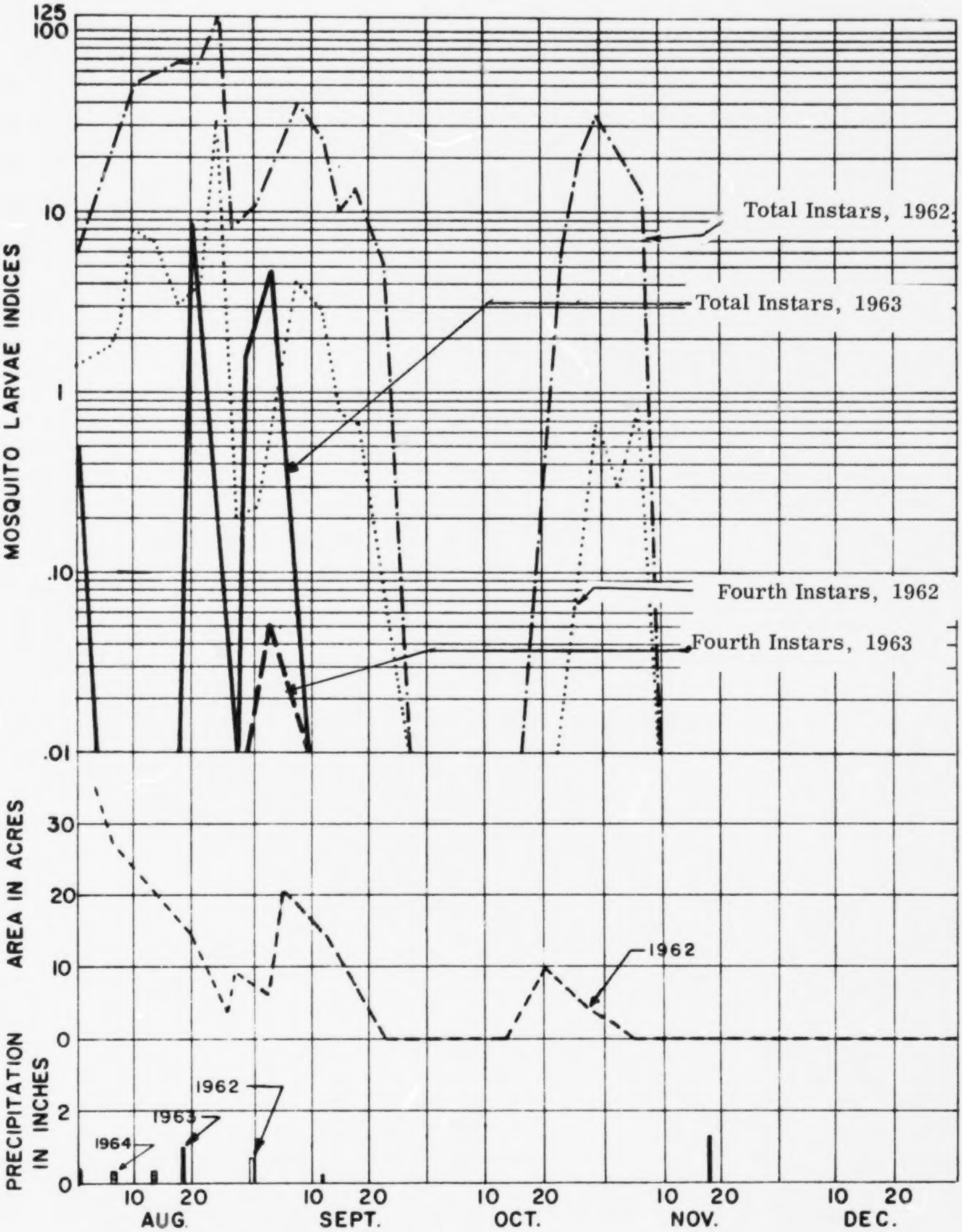

Figure 5B. Mosquito larvae indices presented semi-logarithmically for both fourth instar larvae and total of all instars taken twice weekly during the 1962 season and once weekly during the 1963 and 1964 seasons by sampling at thirty foot intervals on ten transects; in relation to daily surface acres and rainfall. Fall and winter 1962, 1963 and 1964. Lake V (Kitten).

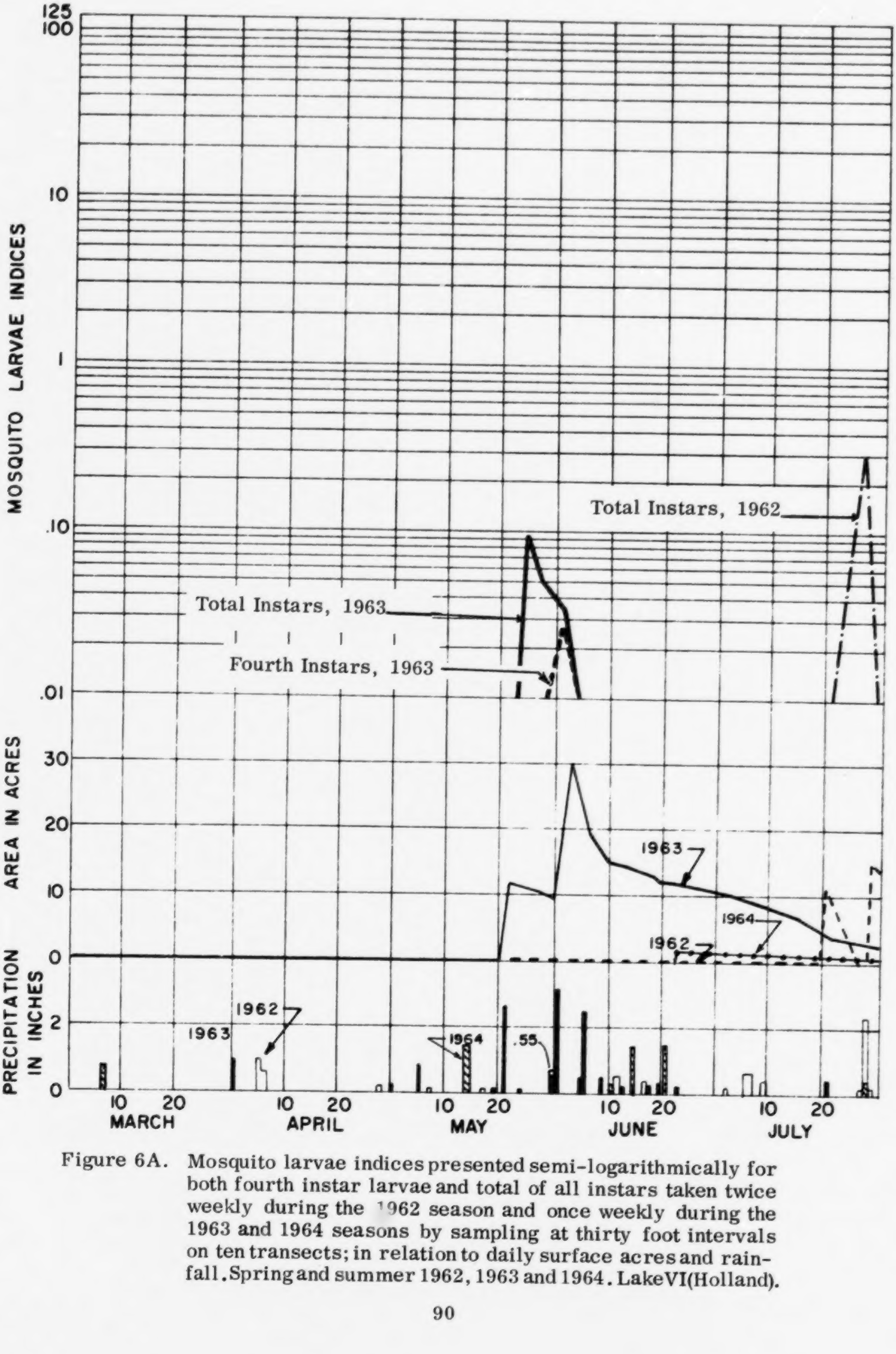

Figure 6A. Mosquito larvae indices presented semi-logarithmically for both fourth instar larvae and total of all instars taken twice weekly during the 1962 season and once weekly during the 1963 and 1964 seasons by sampling at thirty foot intervals on ten transects; in relation to daily surface acres and rainfall. Spring and summer 1962, 1963 and 1964. Lake VI (Holland).

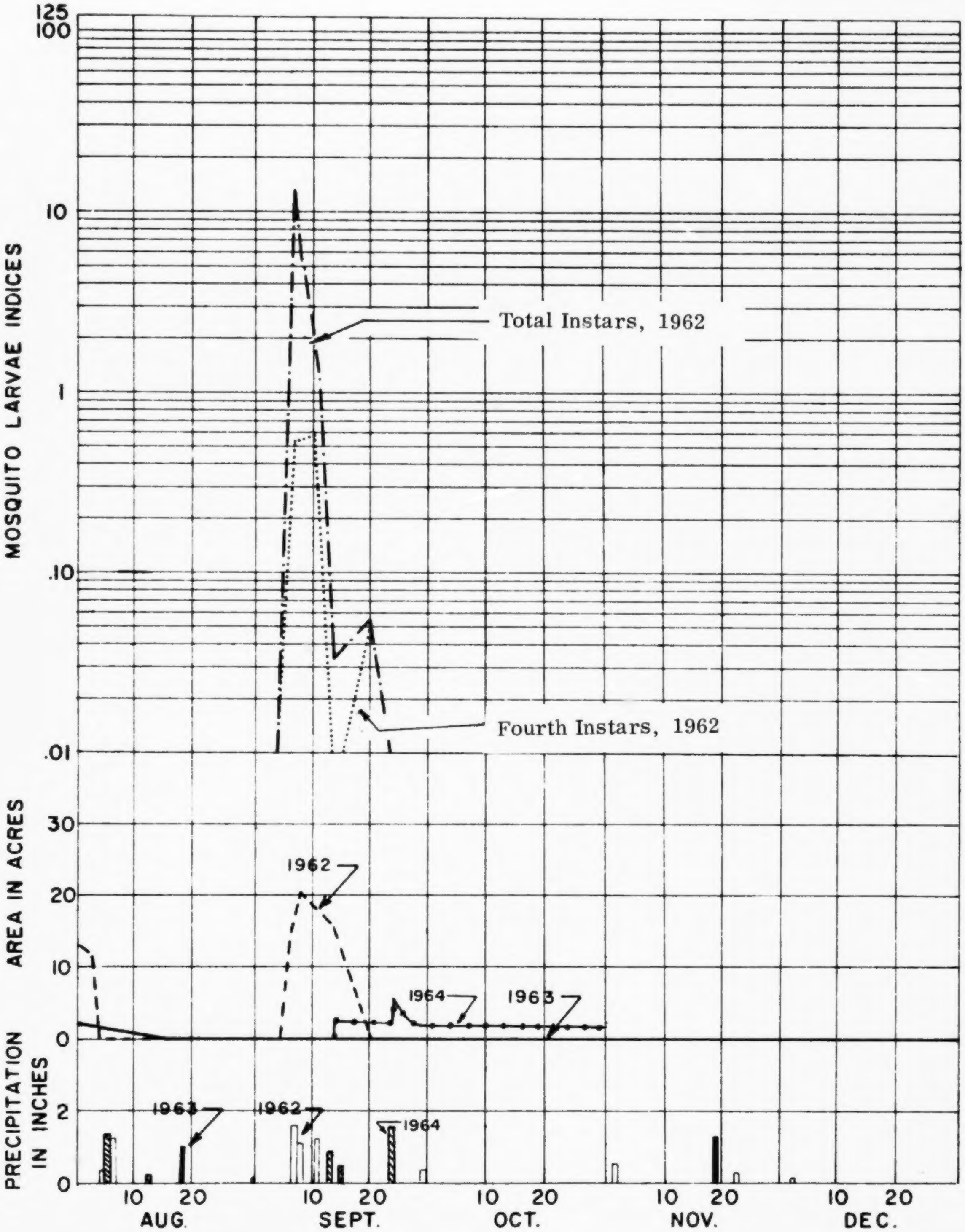

Figure 6B. Mosquito larvae indices presented semi-logarithmically for both fourth instar larvae and total of all instars taken twice weekly during the 1962 season and once weekly during the 1963 and 1964 seasons by sampling at thirty foot intervals on ten transects; in relation to daily surface acres and rainfall. Fall and winter 1962, 1963 and 1964. Lake VI (Holland).

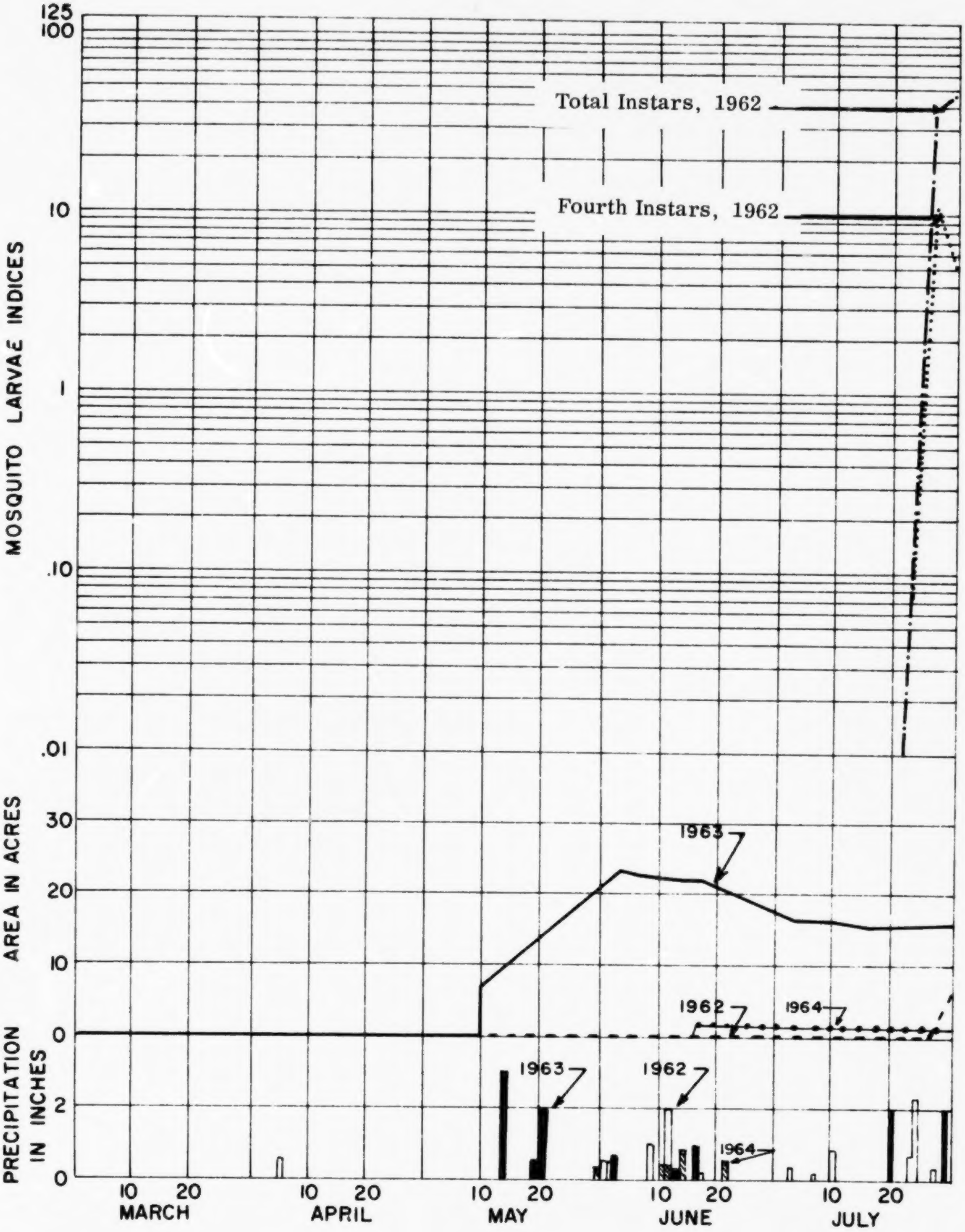

Figure 8A. Mosquito larvae indices presented semi-logarithmically for both fourth instar larvae and total of all instars taken twice weekly during the 1962 season and once weekly during the 1963 and 1964 seasons by sampling at thirty foot intervals on ten transects; in relation to daily surface acres and rainfall. Spring and summer 1962, 1963 and 1964. Lake VIII (Burgett).

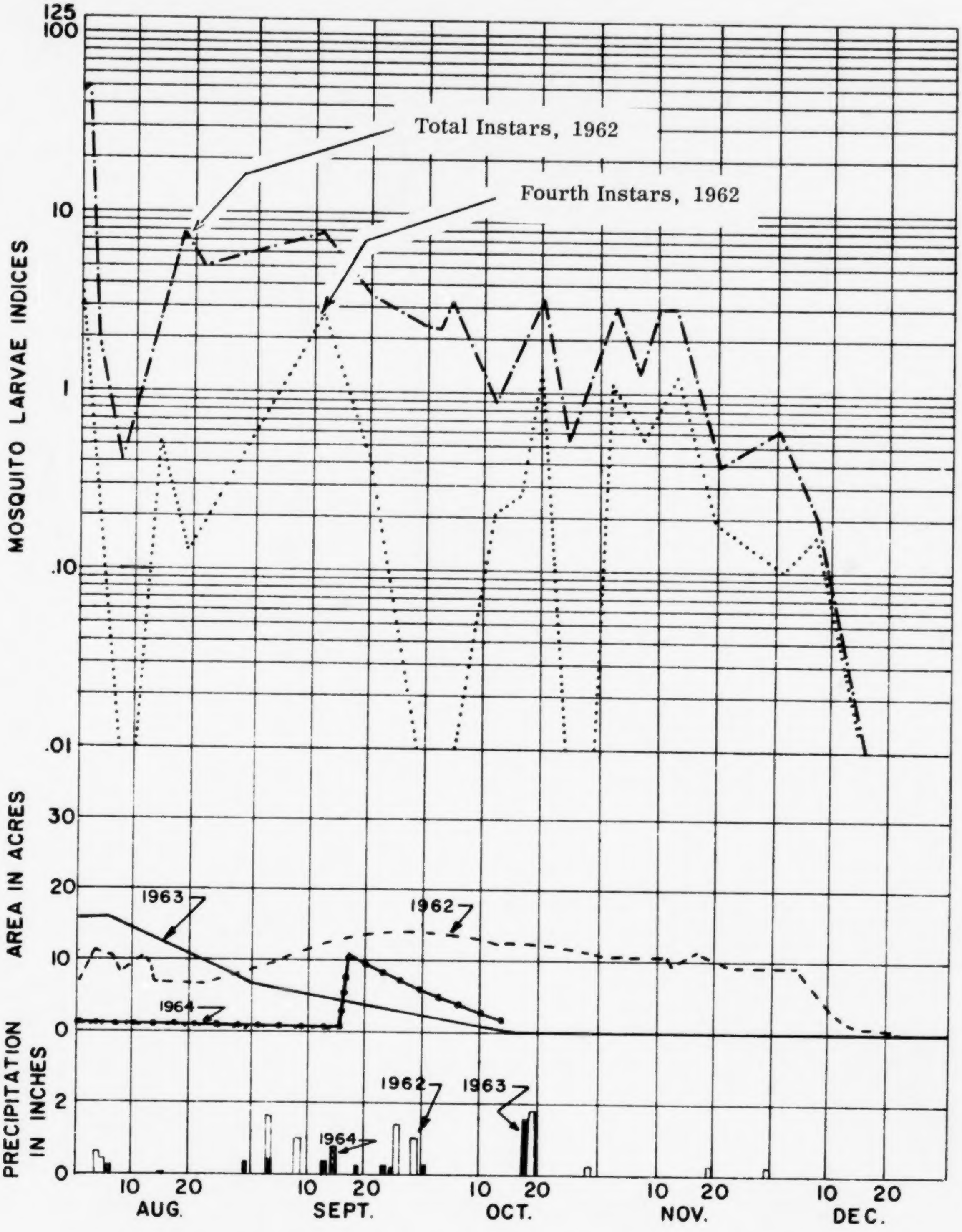

Figure 8B. Mosquito larvae indices presented semi-logarithmically for both fourth instar larvae and total of all instars taken twice weekly during the 1962 season and once weekly during the 1963 and 1964 seasons by sampling at thirty foot intervals on ten transects; in relation to daily surface acres and rainfall. Fall and winter 1962, 1963 and 1964. Lake VIII (Burgett).

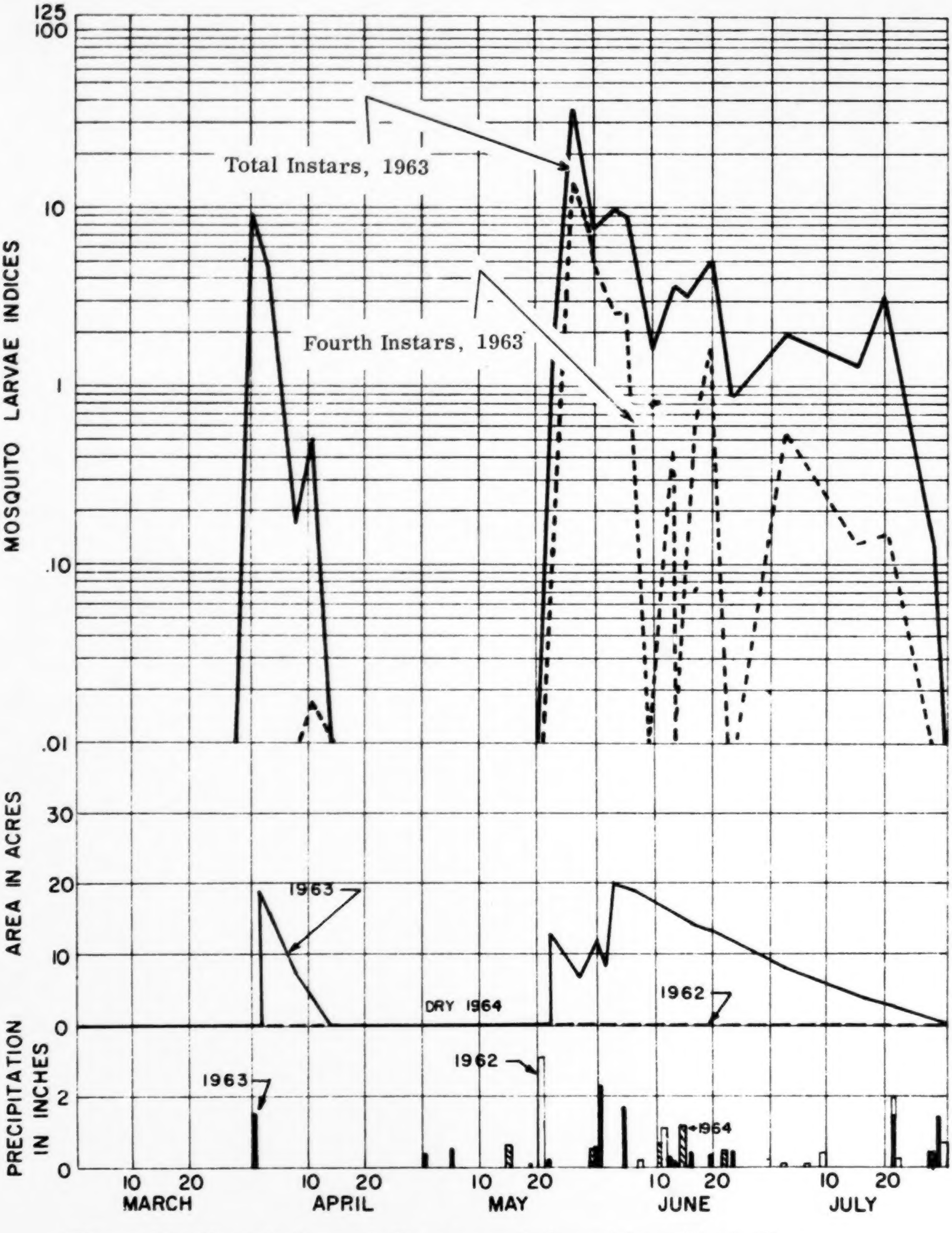

Figure 9A. Mosquito larvae indices presented semi-logarithmically for both fourth instar larvae and total of all instars taken twice weekly during the 1962 season and once weekly twice weekly during the 1962 season and once weekly during the 1963 and 1964 **seasons** by sampling at thirty foot intervals on ten transects; in relation to daily surface acres and rainfall. Spring and summer 1962, 1963 and 1964. Lake IX (Cox).

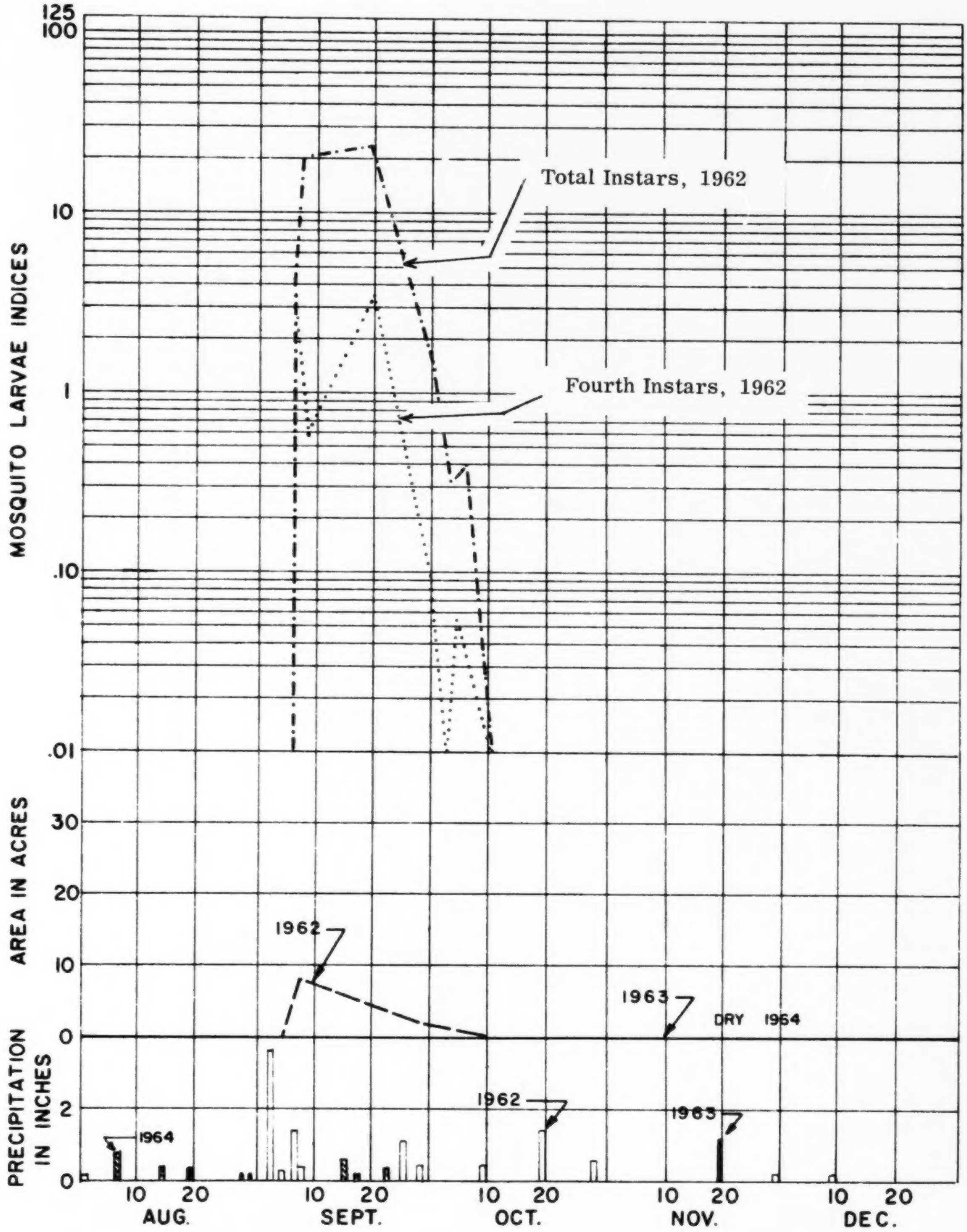

Figure 9B. Mosquito larvae indices presented semi-logarithmically for both fourth instar larvae and total of all instars taken twice weekly during the 1962 season and once weekly during the 1963 and 1964 seasons by sampling at thirty foot intervals on ten transects; in relation to daily surface acres and rainfall. Fall and winter 1962, 1963 and 1964. Lake IX (Cox).

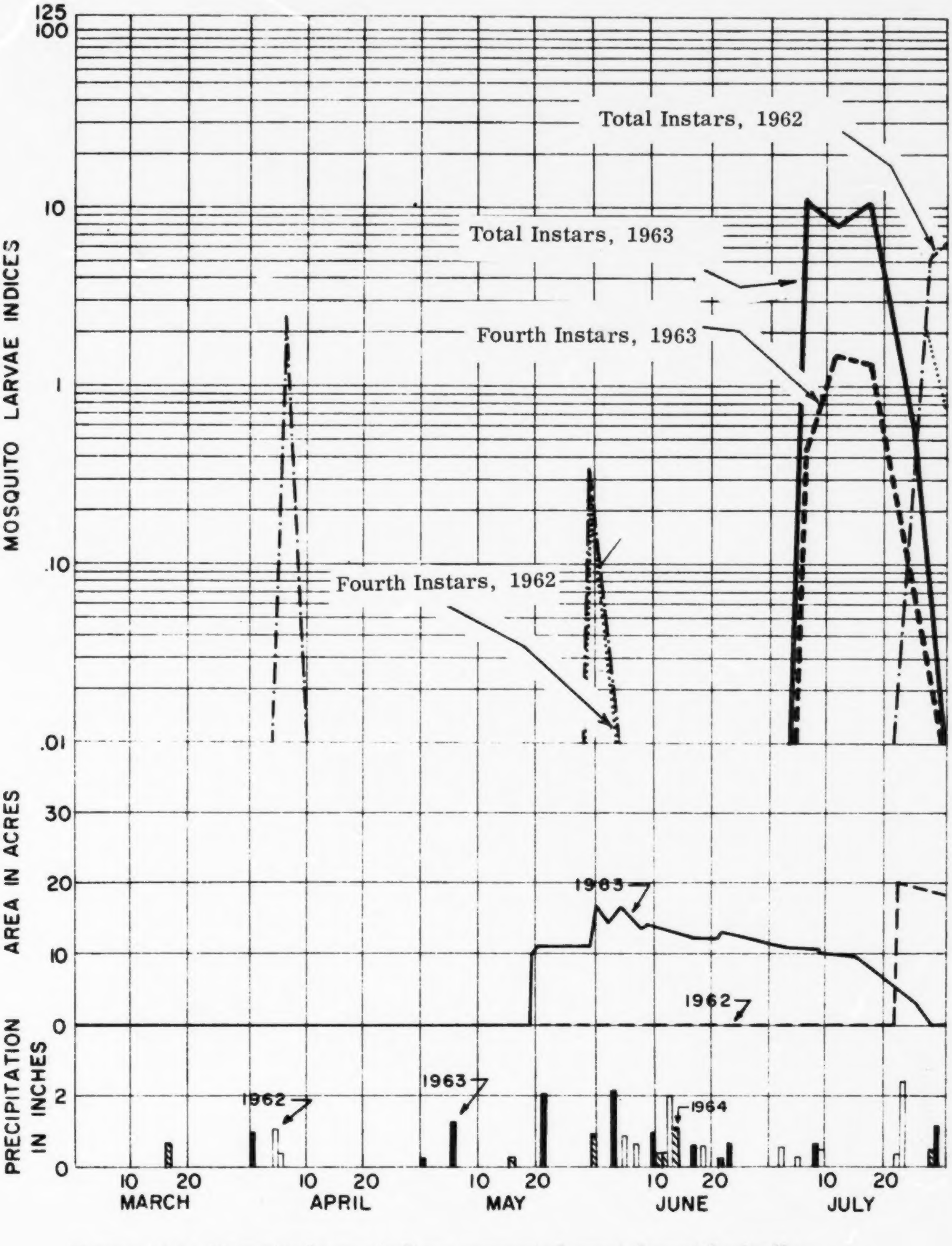

Figure 10A. Mosquito larvae indices presented semi-logarithmically for both fourth instar larvae and total of all instars taken twice weekly during the 1962 season and once weekly during the 1963 and 1964 seasons by sampling at thirty foot intervals on ten transects; in relation to daily surface acres and rainfall. Spring and summer 1962, 1963 and 1964. Lake X (Dupree).

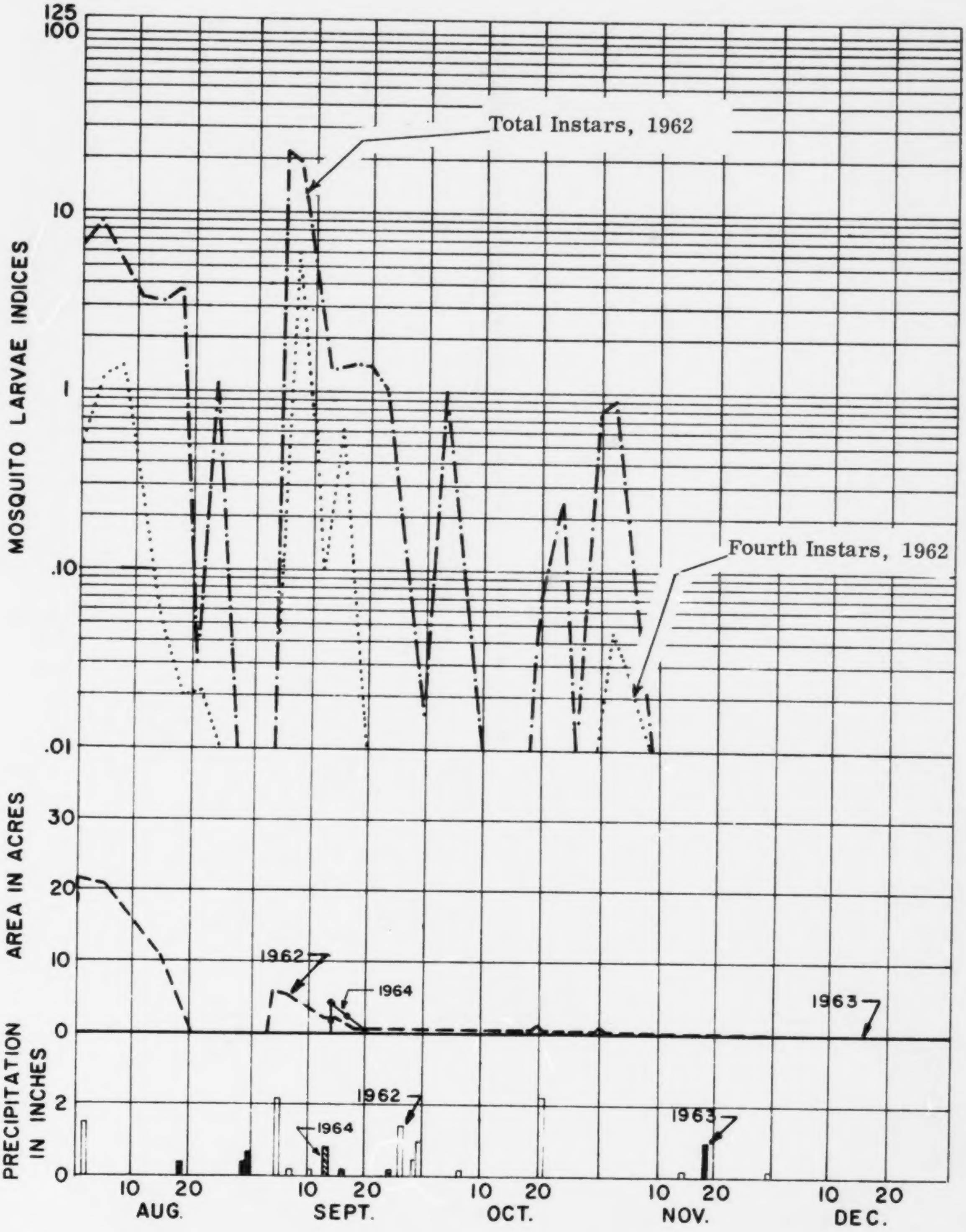

Figure 10B. Mosquito larvae indices presented semi-logarithmically for both fourth instar larvae and total of all instars taken twice weekly during the 1962 season and once weekly during the 1963 and 1964 seasons by sampling at thirty foot intervals on ten transects; in relation to daily surface acres and rainfall. Fall and winter 1962, 1963 and 1964. Lake X (Dupree).

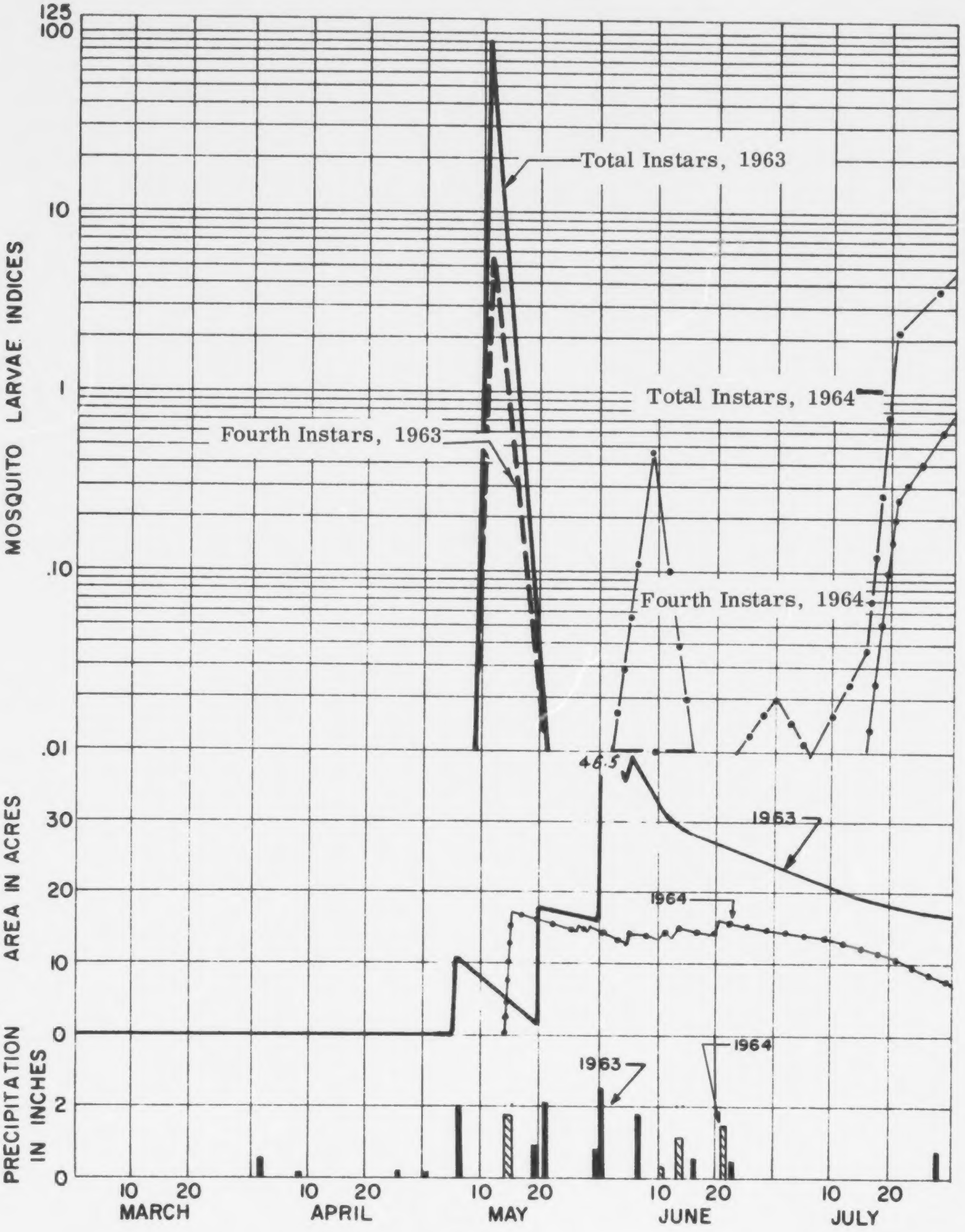

Figure 11A. Mosquito larvae indices presented semi-logarithmically for both fourth instar larvae and total of all instars taken once weekly by sampling at thirty foot intervals on ten transects; in relation to daily surface acres and rainfall. Spring and summer 1963 and 1964 Lake XI (Krueger).

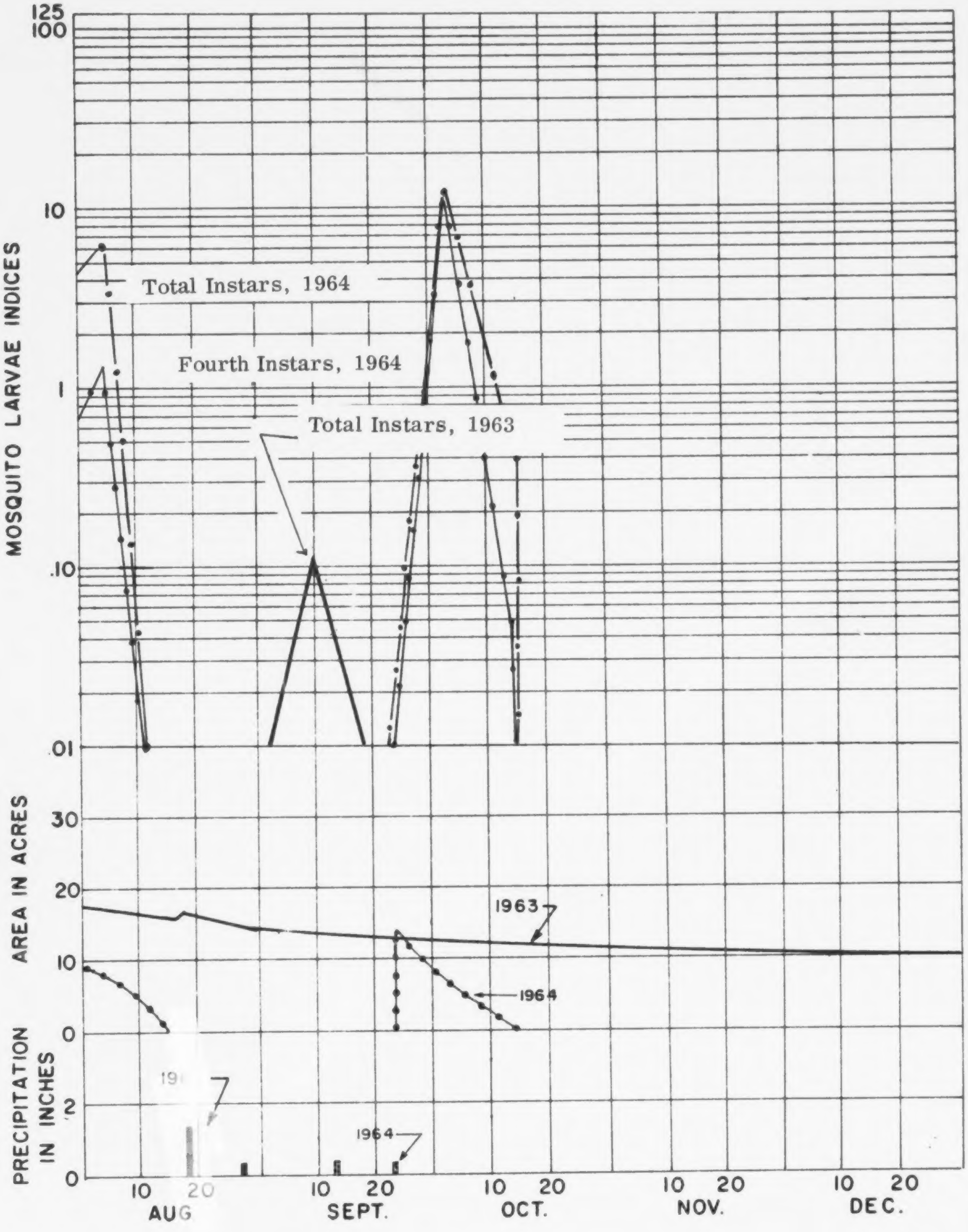

Figure 11B. Mosquito larvae indices presented semi-logarithmically for both fourth instar larvae and total of all instars taken once weekly by sampling at thirty foot intervals on ten transects; in relation to daily surface acres and rainfall. Fall and winter 1963 and 1964. Lake XI (Krueger).

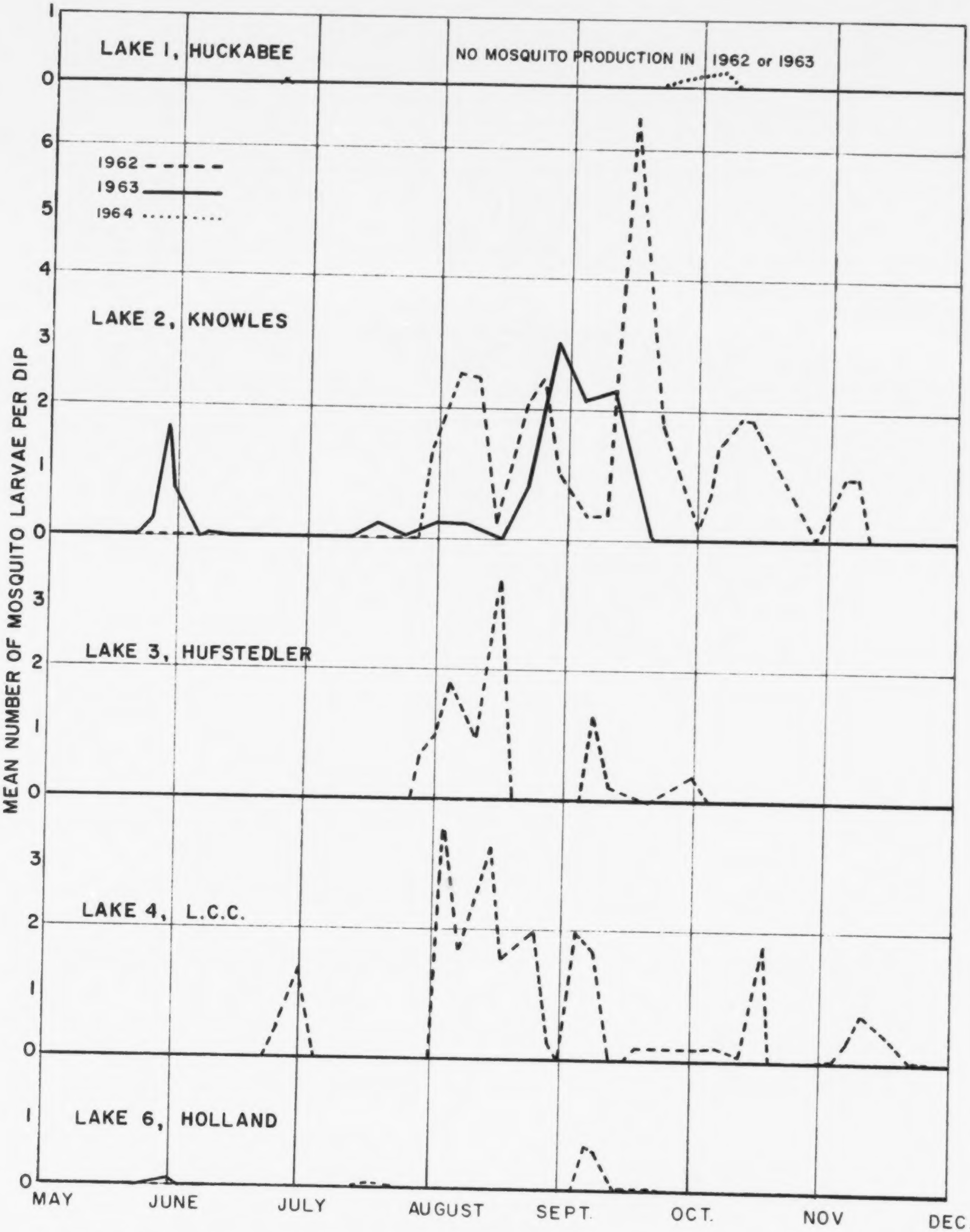

Figure 12A. Mean numbers of mosquito larvae per dip taken once or twice weekly by sampling at thirty foot intervals on ten transects on each lake presented for both the 1962, 1963 and 1964 seasons. Lubbock County, Texas

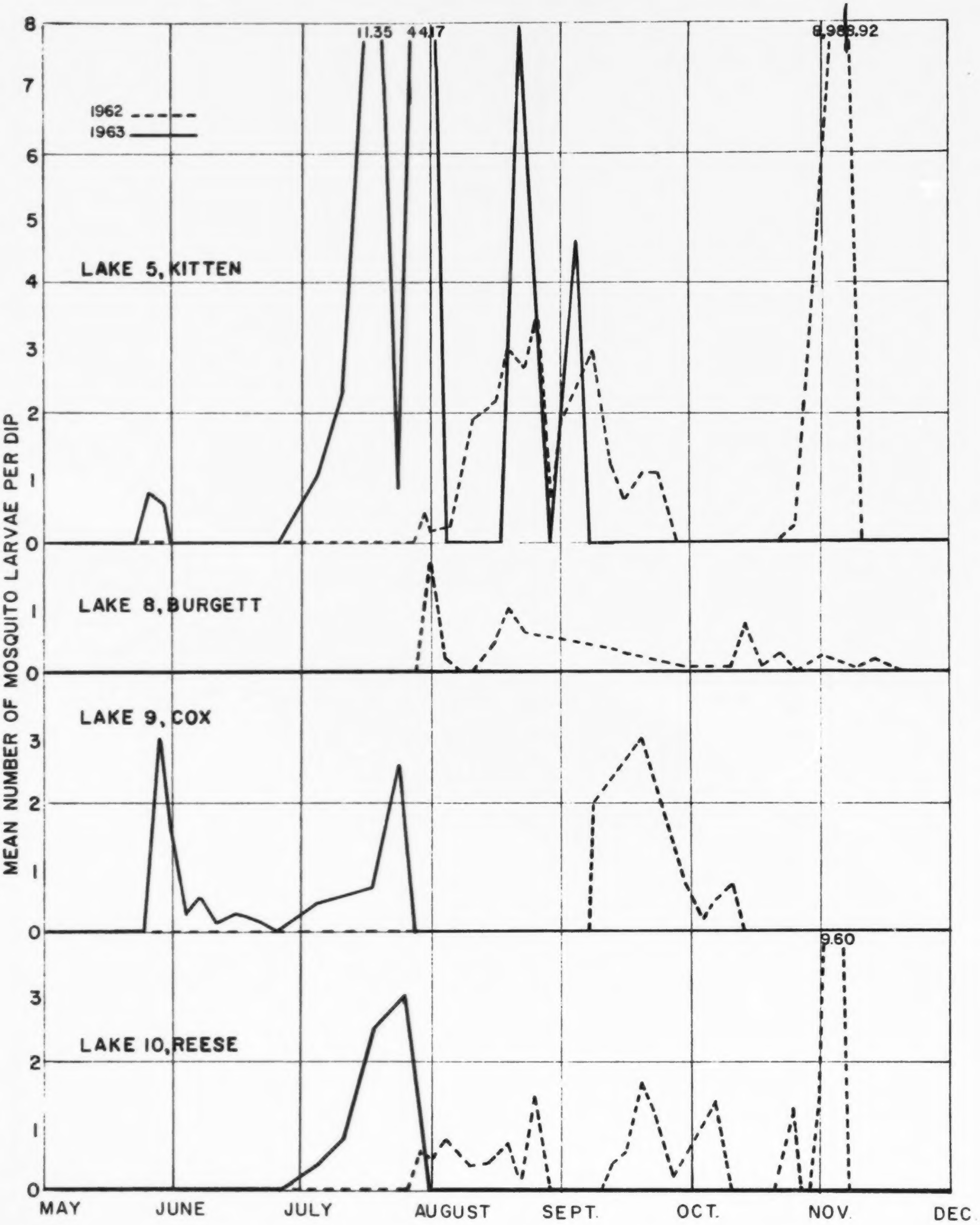

Figure 12B. Mean numbers of mosquito larvae per dip taken once or twice weekly by sampling at thirty foot intervals on ten transects on each lake presented for both the 1962, 1963 and 1964 seasons. Lubbock County, Texas.

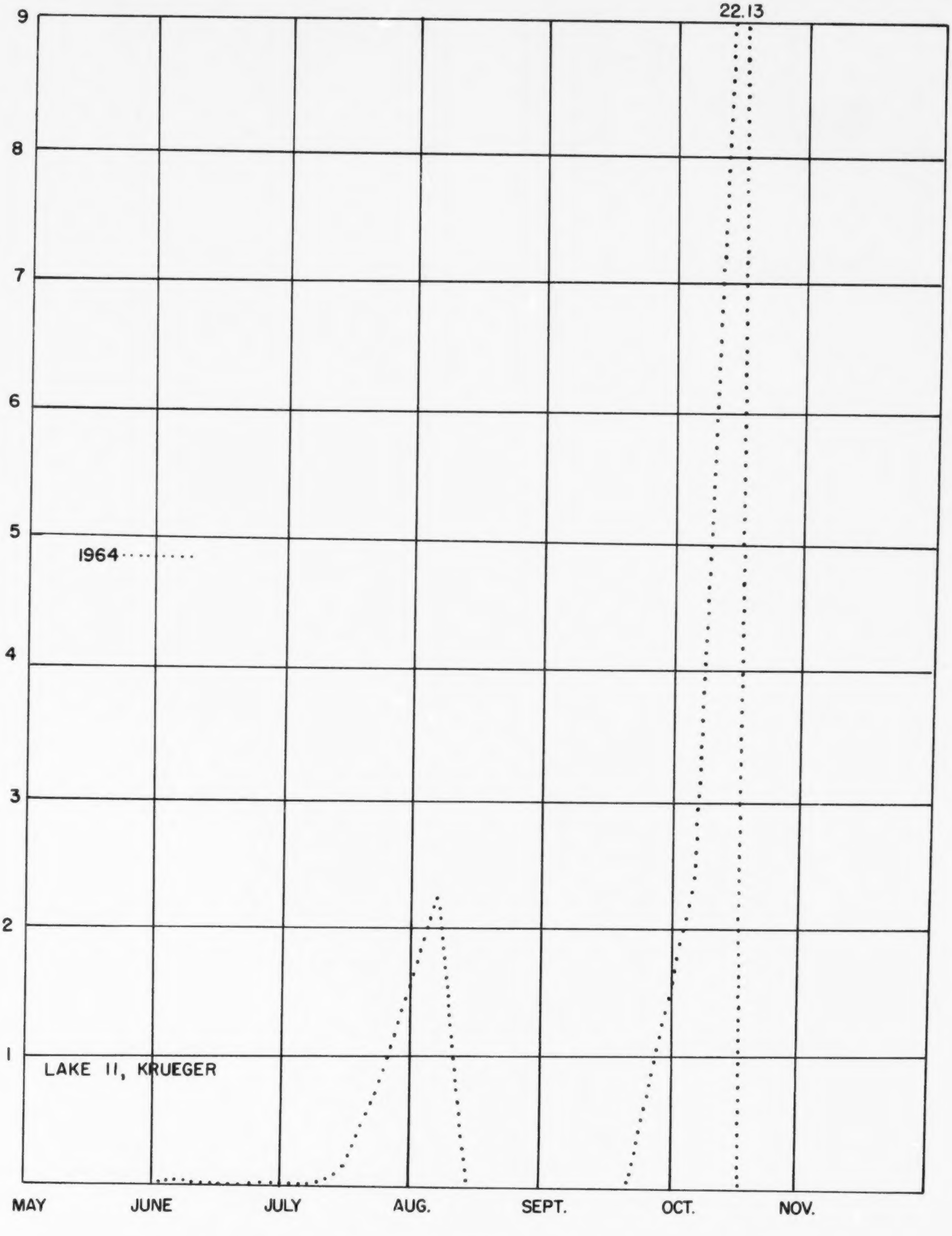

Figure B. (Continued) Mean number of mosquito larvae per dip taken once weekly by sampling at thirty foot intervals on ten transects on Krueger lake for 1964 season. Lubbock County, Texas.

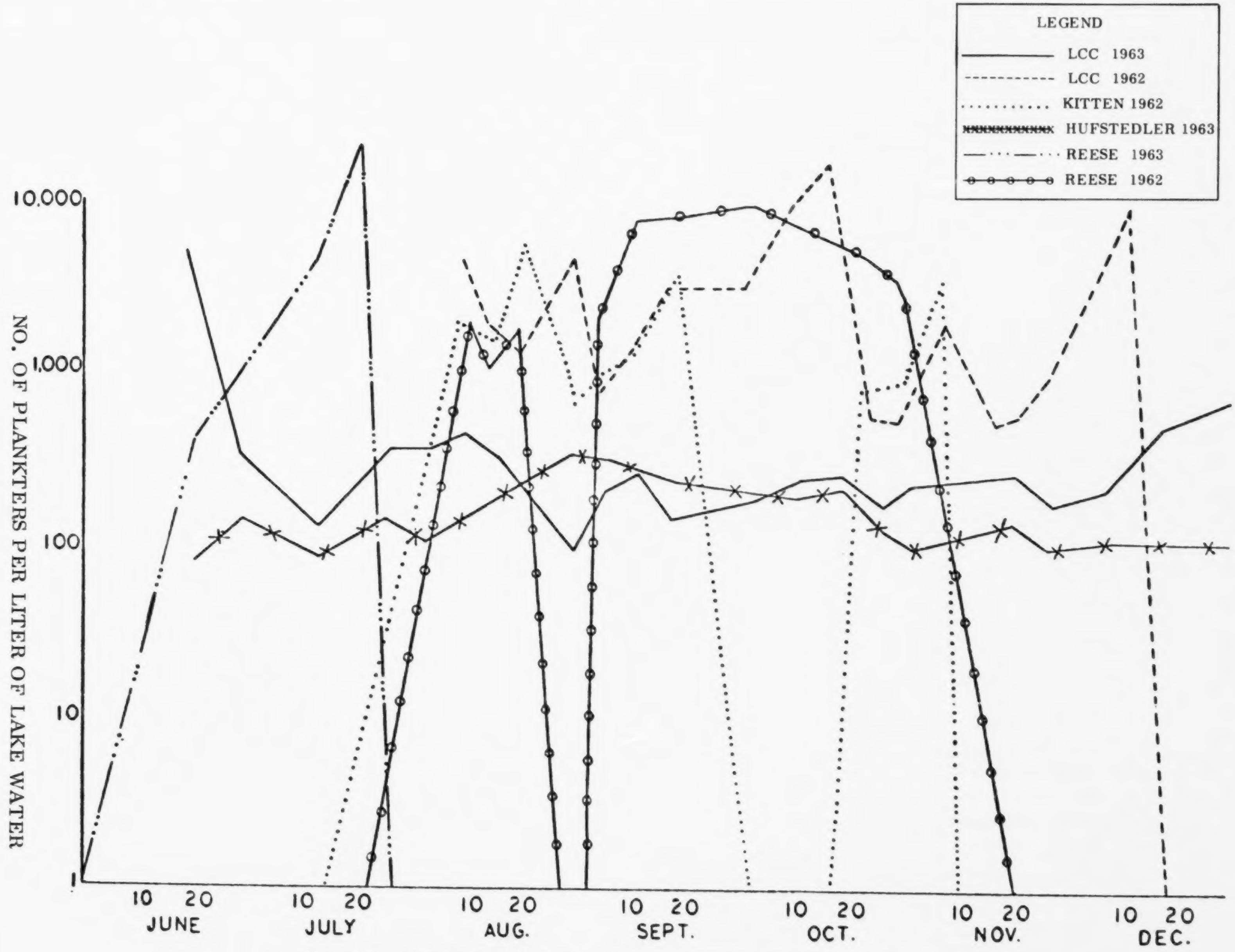

Fig. 13. --Mean Numbers of All Net Plankton Per Liter of Lake Water in Duplicate Samples from Four Lakes. 1962 and 1963 Seasons.

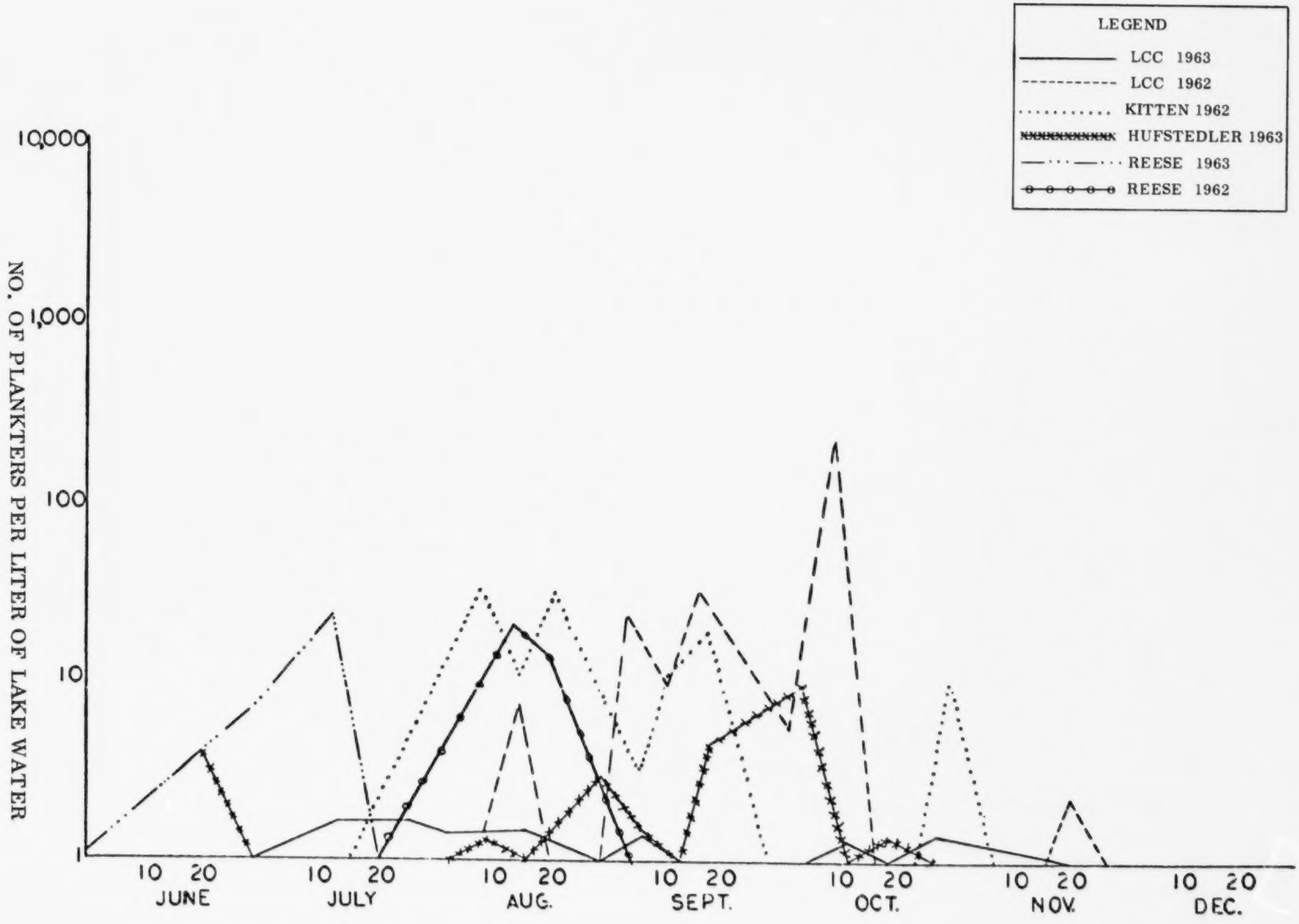

Fig. 14. --Mean Numbers of Plankton (Family Macrothricidae) Per Liter of Lake Water in Duplicate Samples from Four Lakes. 1962 and 1963 Seasons.

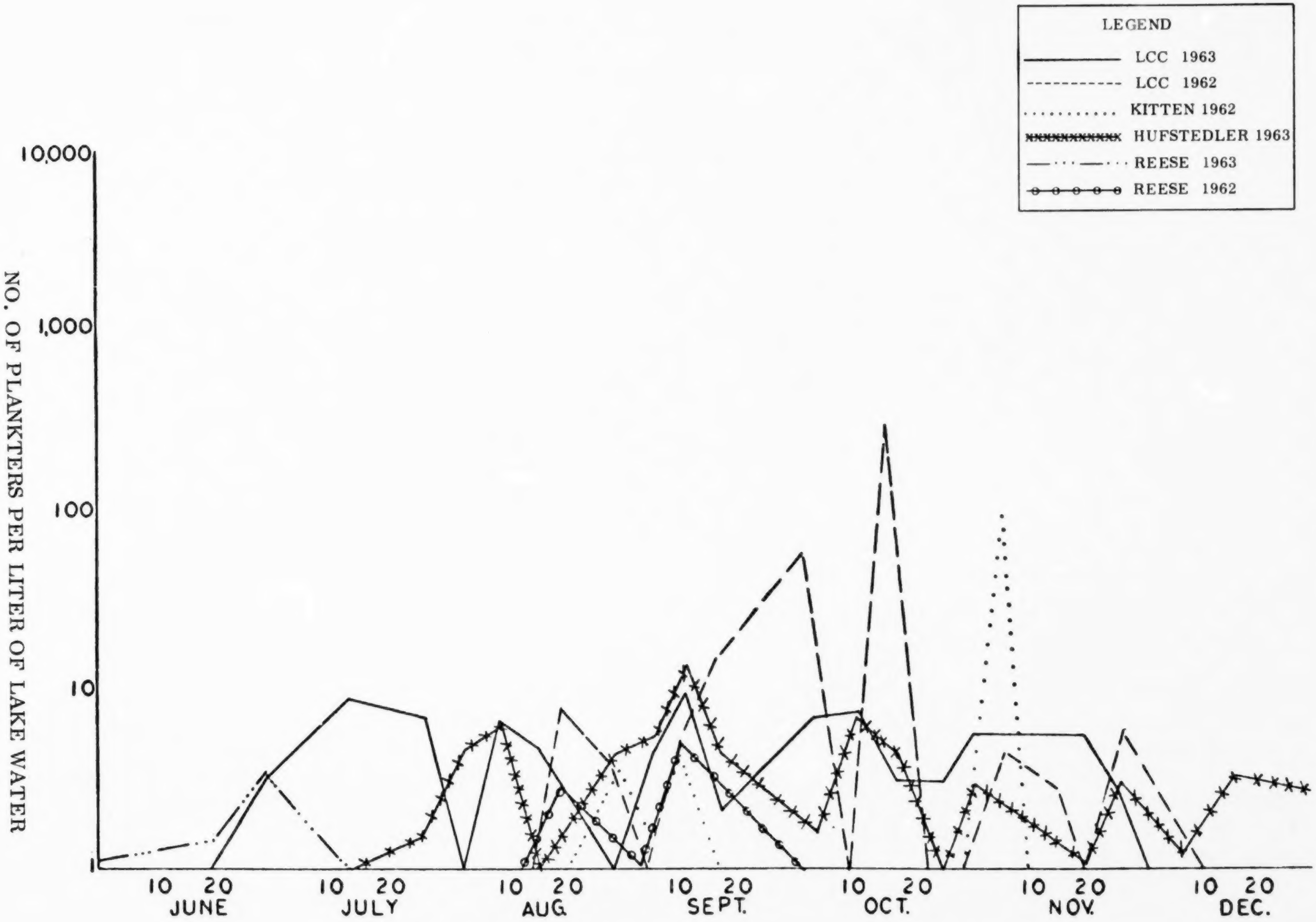

Fig. 15. --Mean Numbers of Plankton (Suborder Calanoida) Per Liter of Lake Water in Duplicate Samples from Four Lakes. 1962 and 1963 Seasons.

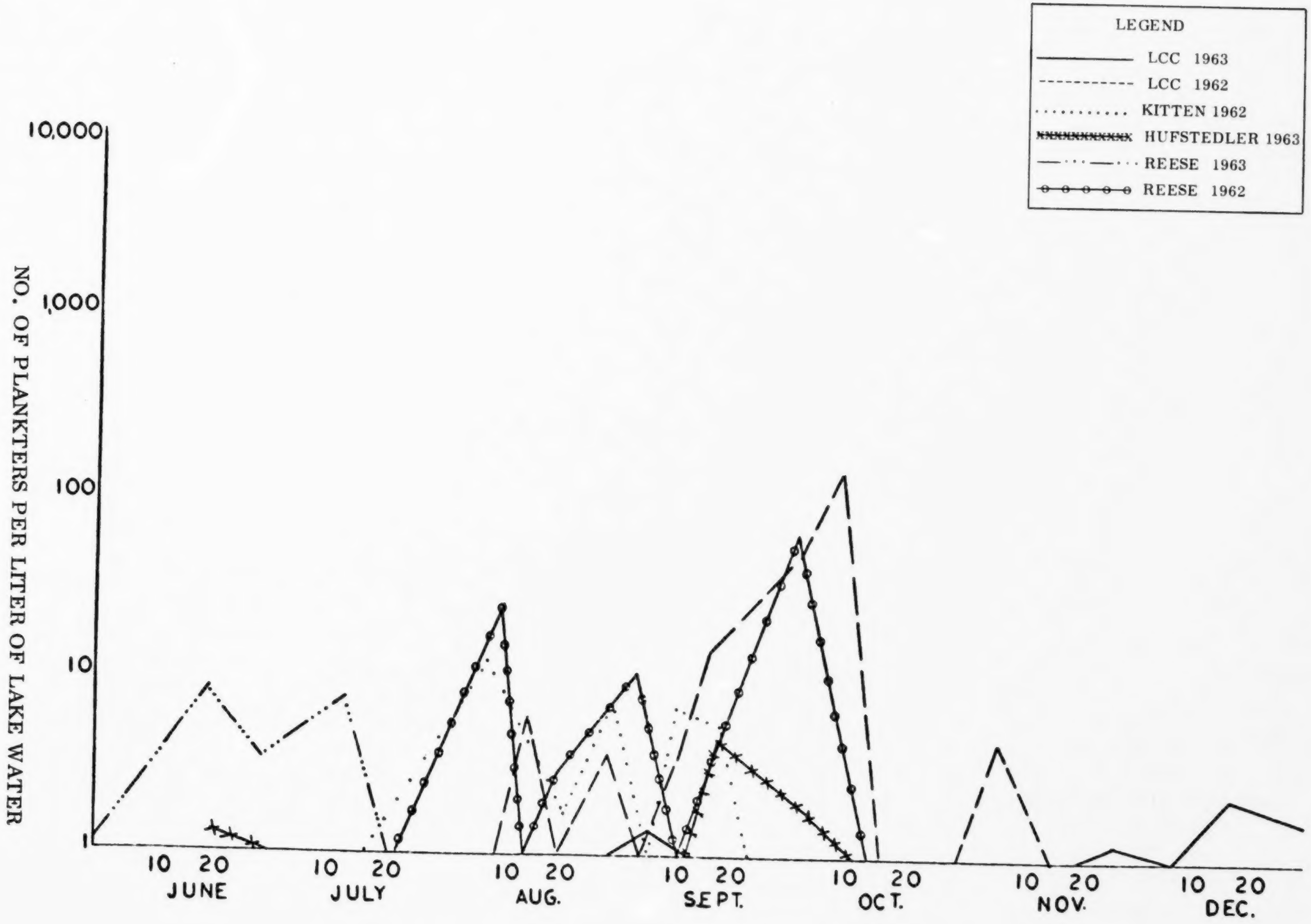

Fig. 16. --Mean numbers of Plankton (Suborder Cyclopoida) Per Liter of Lake Water in Duplicate Samples from Four Lakes. 1962 and 1963 Seasons.

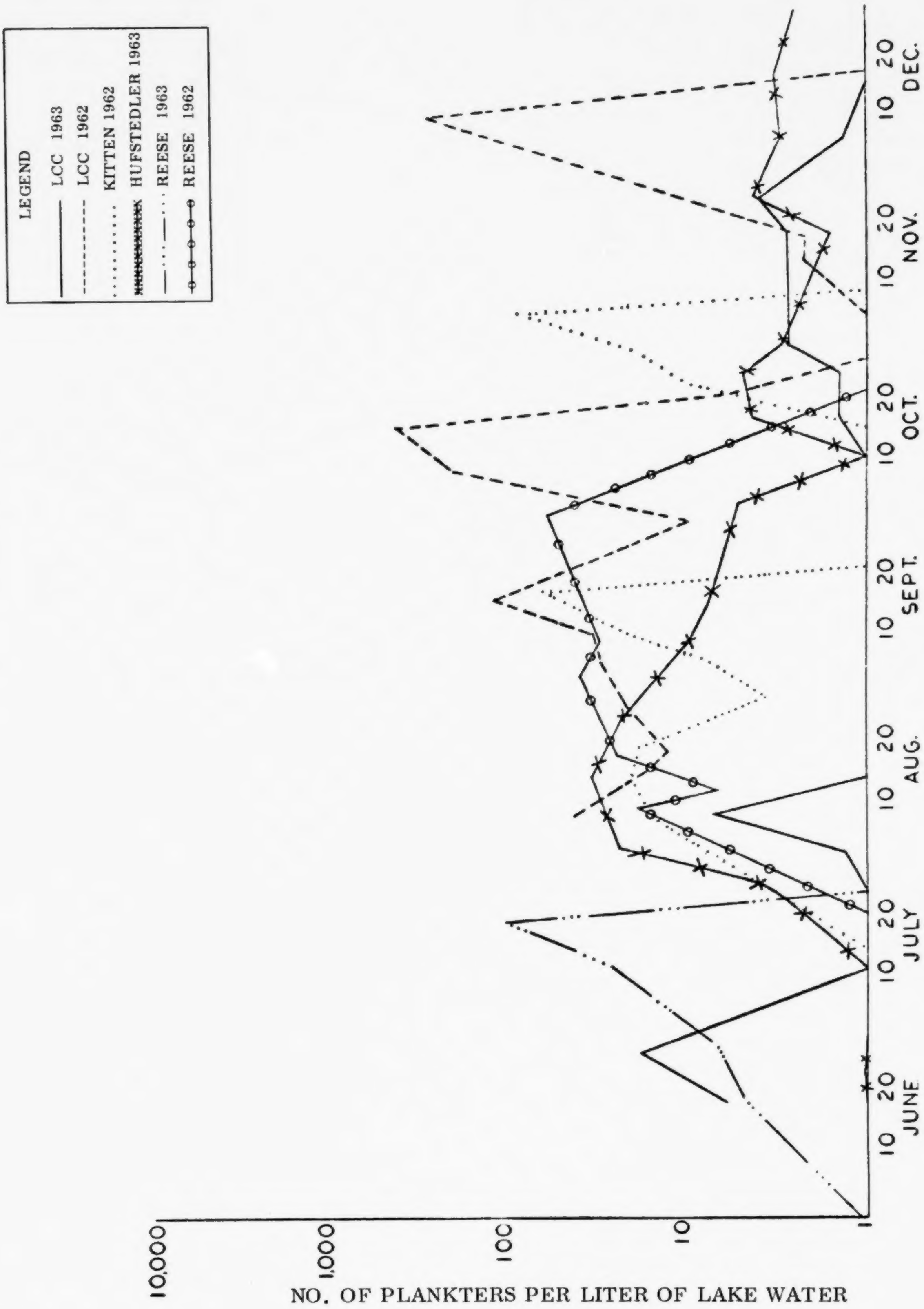

Fig. 17. --Mean Numbers of Plankton (Phylum Rotifera) Per Liter of Lake Water in Duplicate Samples from Four Lakes. 1962 and 1963 Seasons.

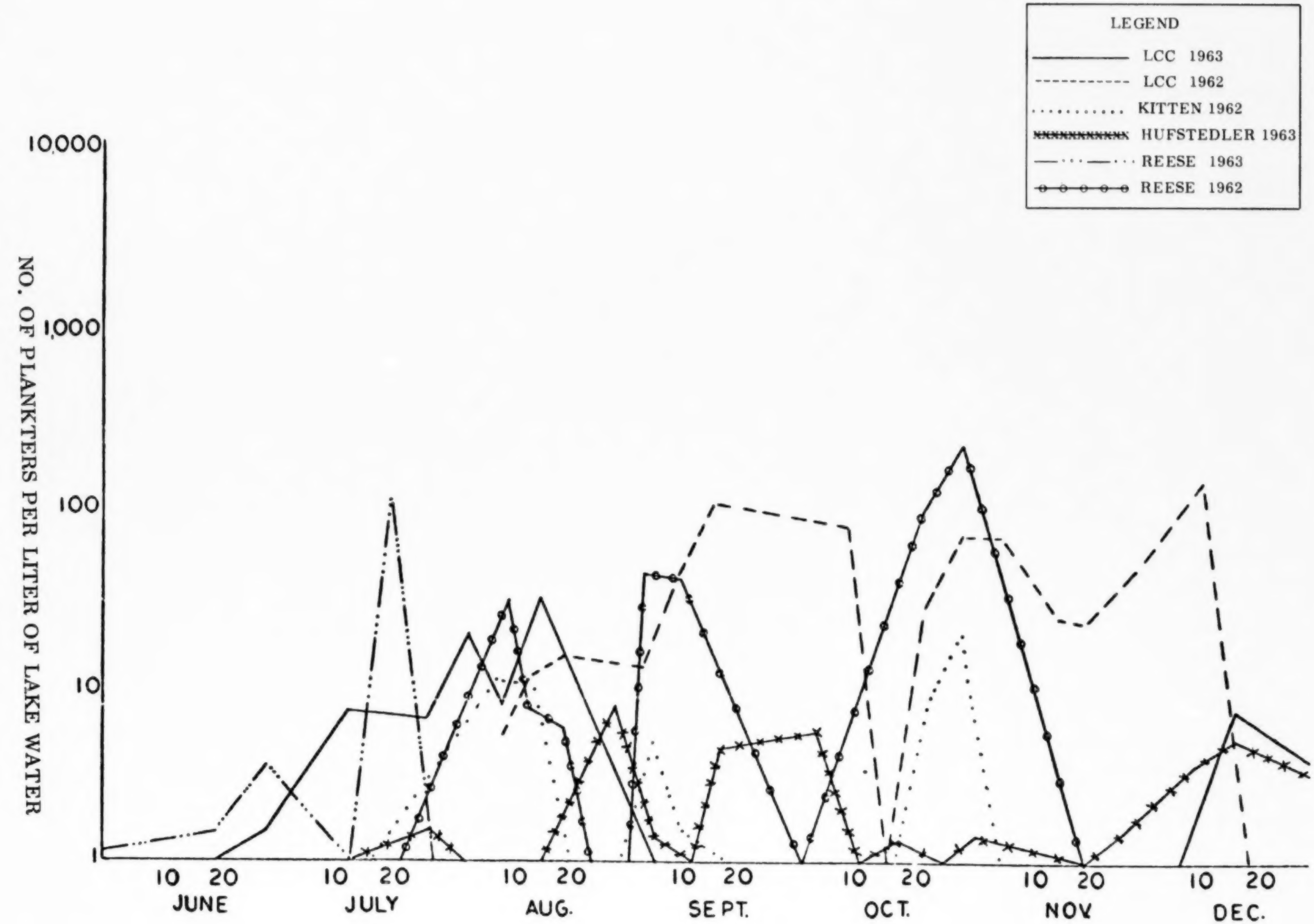

Fig. 18. --Mean Numbers of Plankton (Class Nematoda) Per Liter of Lake Water in Duplicate Samples from Four Lakes. 1962 and 1963 Seasons.

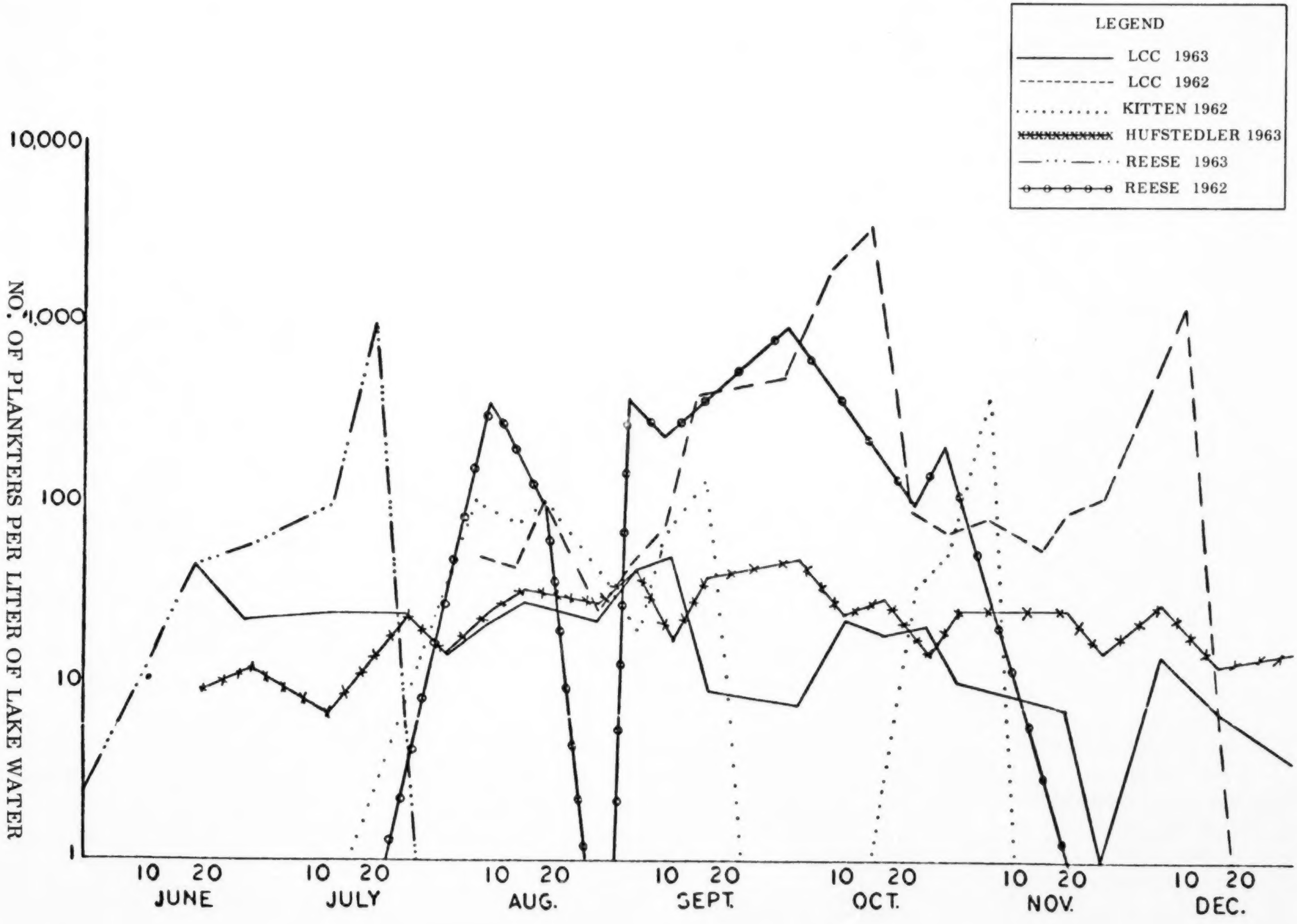

Fig. 19. --Mean Numbers of Plankton (Superclass Rhizopoda) Per Liter of Lake Water in Duplicate Samples from Four Lakes. 1962 and 1963 Seasons.

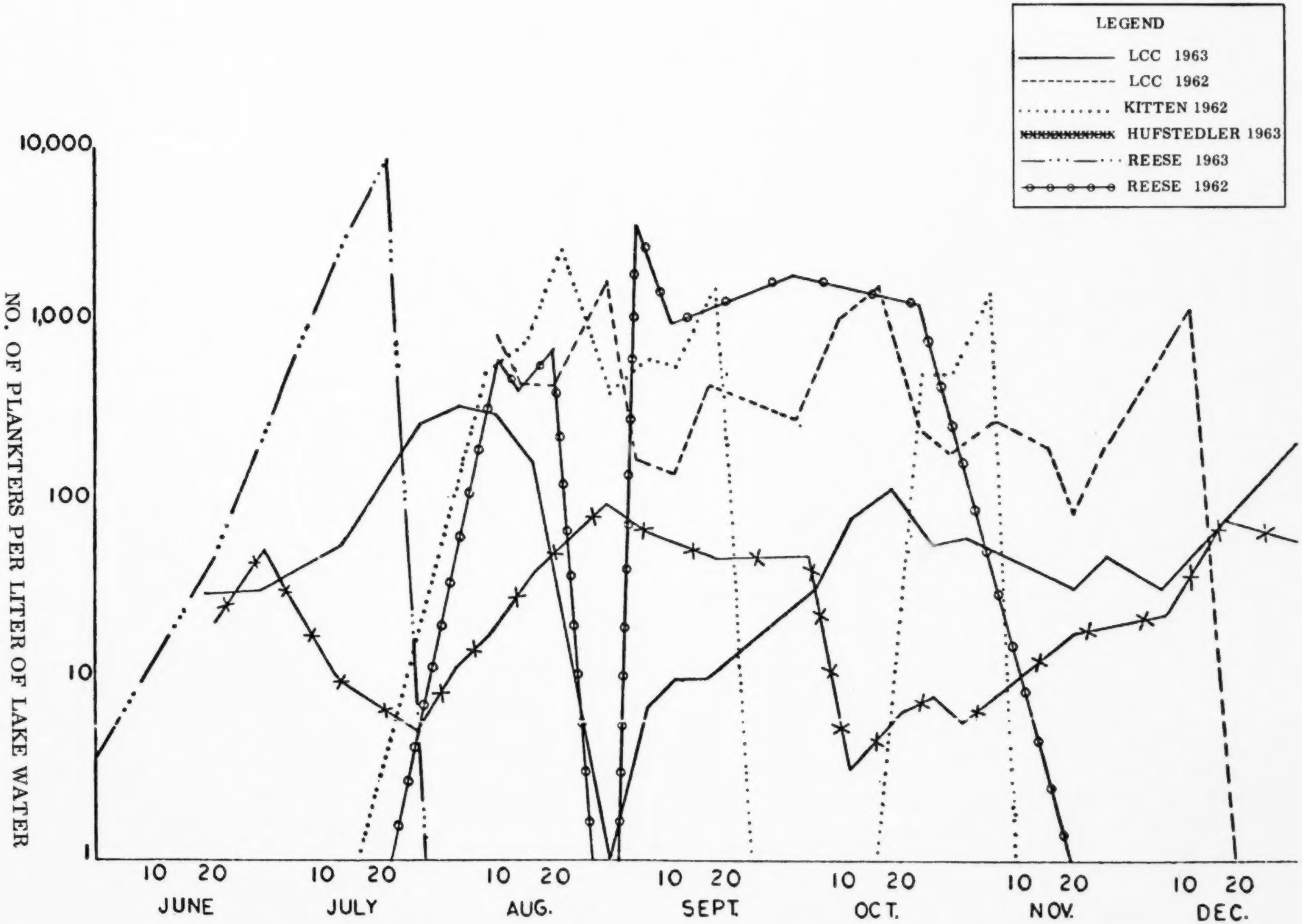

Fig. 20. --Mean Numbers of Plankton (Division Cyanophyta) Per Liter of Lake Water in Duplicate Samples from Four Lakes. 1962 and 1963 Seasons.

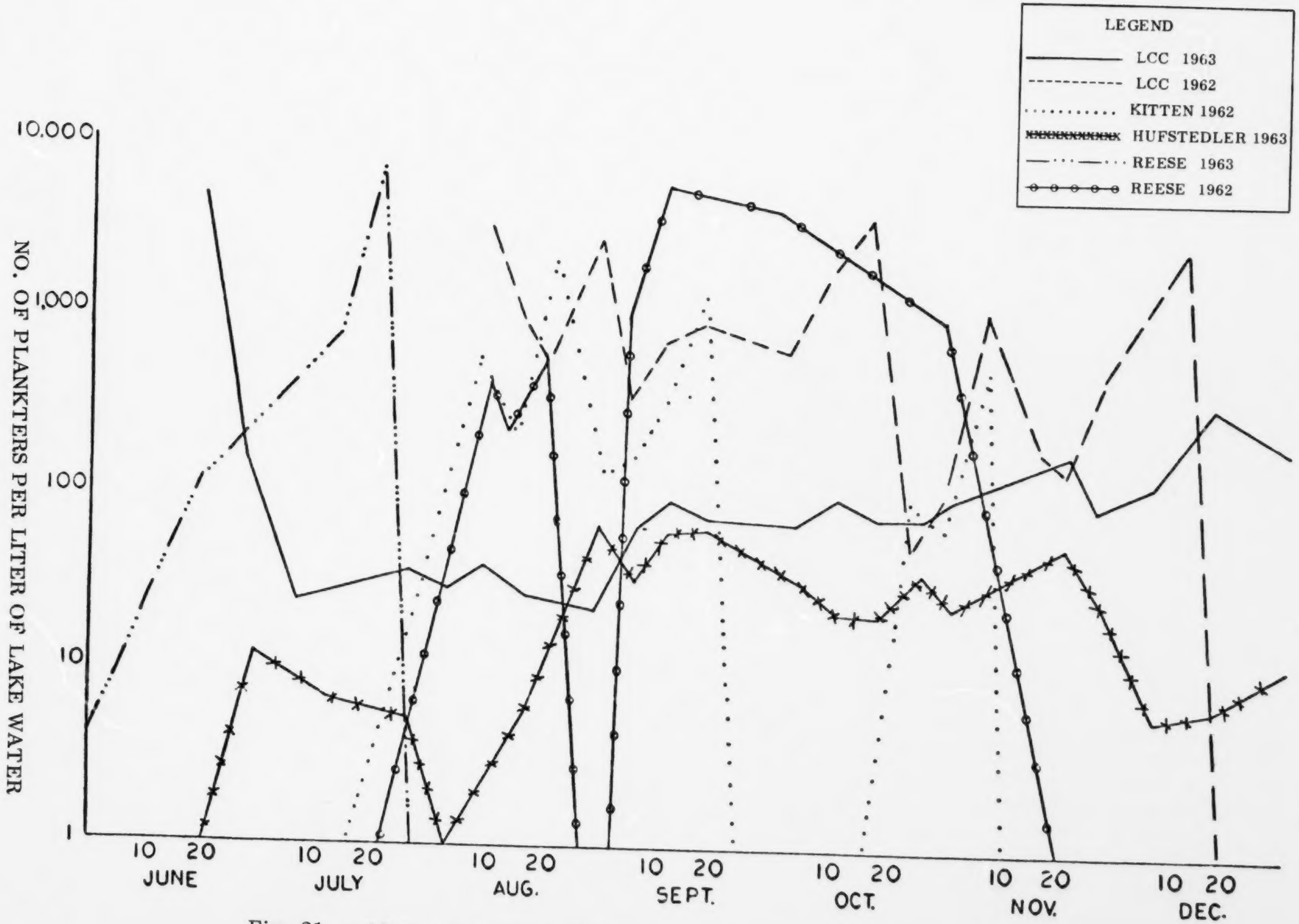

Fig. 21. --Mean Numbers of Plankton (Class Bacillariophyceae) Per Liter of Lake Water in Duplicate Samples from Four Lakes. 1962 and 1963 Seasons.

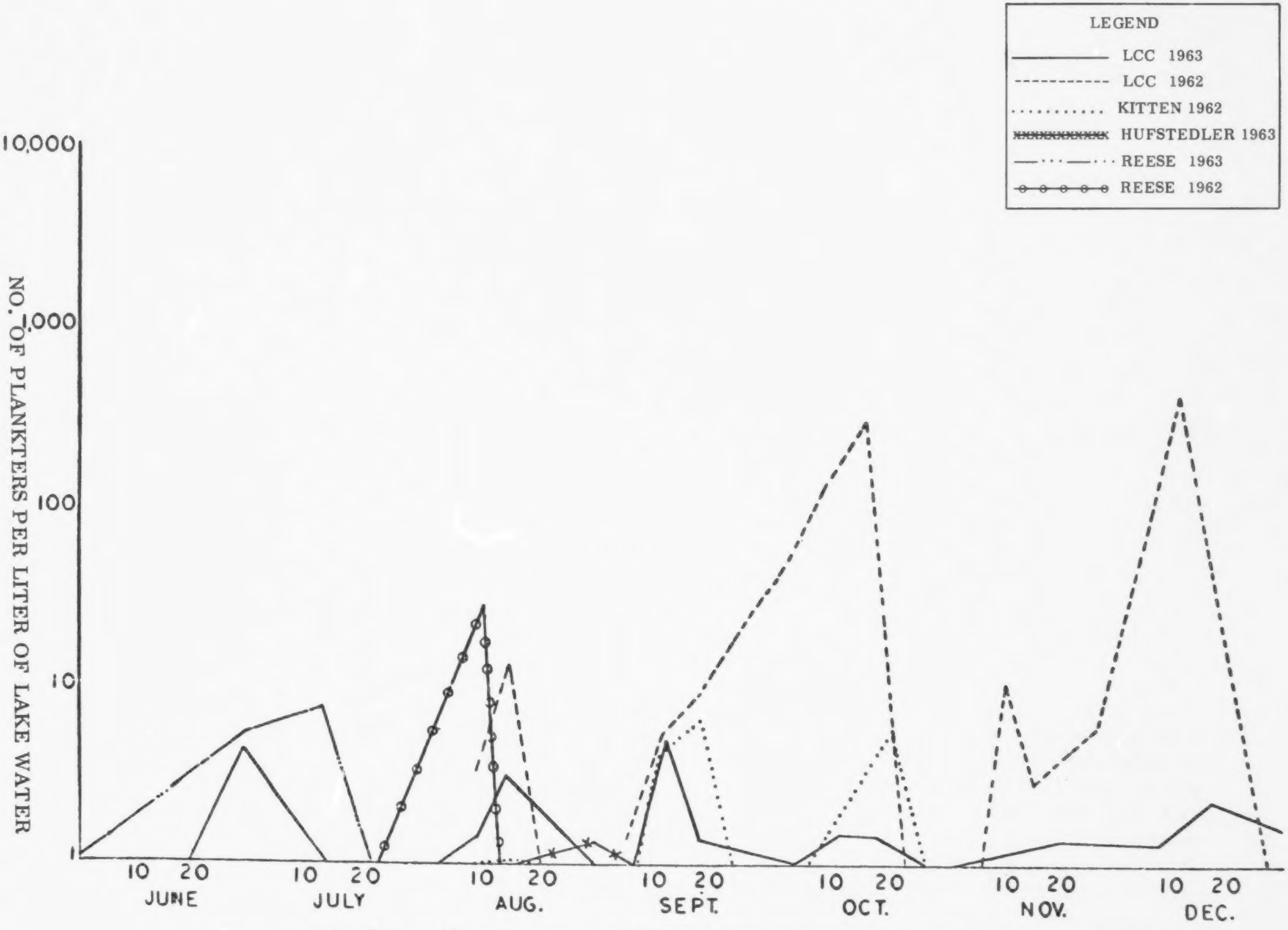

Fig. 23. --Mean Numbers of Plankton (Family Daphnidae) Per Liter of Lake Water in Duplicate Samples from Four Lakes. 1962 and 1963 Seasons.

Vegetative Observations on Modified and Unmodified Lakes

Table 3

Part I Vegetative Plots on Hufstedler, LCC and Krueger lakes. One square yard plots were staked on transects and read once a month.

Species	Date			
	June 20, 1964	July 16, 1964	August 12, 1964	Sept. 16, 1964
Polygonum lapthifolium	--	83	360	60
Amaranthus Spp	113	87	25	70
Echinochloa crusgalli	7	502	127	87
Polygonum aviculare	--	5	--	6
Helianthus ciliata	--	22	42	--
Oenothera		34		
Conyza canadensis	--	5	54	
Marsilea	—	--	204	--
Erogrostis	--	1	--	1
Plantago	--	--	--	12
Mollugo verticillata	--	1	--	9
Sphaeralacea	--	38	--	--
Salsola Kali	2	--	--	--

Part II Dominant species of Emergent Plants Found on Unmodified Study Lakes, 1964, Lubbock County, Texas.

Name of Lake	SPRING	SUMMER	FALL
Huckabee #I	Amaranthus spp.	Amaranthus spp. Malvaceae (mallow)	Polygonum lapthifolium
Knowles #II	Sagitaria longiloba (arrowhead) P. lapthifolium (smartweed)	P. lapthifolium	Polygonum lapthifolium
Kitten #V Unmod.	Eleochris spp. (rush)	Eleochris (rush) P. aviculare	Eleochris(rush)
Cox #IX	P. lapthifolium (smartweed)		
Reese #X	Eleochris (rush)	Eleochris (rush)	Eleochris
Krueger #XI	Marsilea (fern) P. lapthifolium (smartweed)	Marsilea P. lapthifolium	P. lapthifolium Echinocholoa crusgalli
Idalou Pit #XII	Sagitaria longiloba (arrowhead) Eleochris (rush)	Eleochris (rush) Sagitaria longiloba (arrowhead)	

Table 3-Continued.
Part III Dominant species of Plants Found on Modified Study Lakes
1964, Lubbock County, Texas

Name of Lake			
Burgett	*Helianthus cilatus*	*Helianthus ciliatus*	plowed & sowed in wheat
Holland VI	*Amaranthus* spp.	*Amaranthus* spp.	*Amaranthus* spp.
Hufstedler III	*Amaranthus* spp.	*Amaranthus* spp.	*Plowed*
Kitten V	*Amaranthus* spp.	*Amaranthus* spp. *Echinocholoa crusgalli*	
LCC IV	*Polygonum lapthifolium* *Amaranthus*, *Echinocholoa crusgalli*	*Polygonum lapthifolium*, *Amaranthus*	*Polygonum lapthifolium*